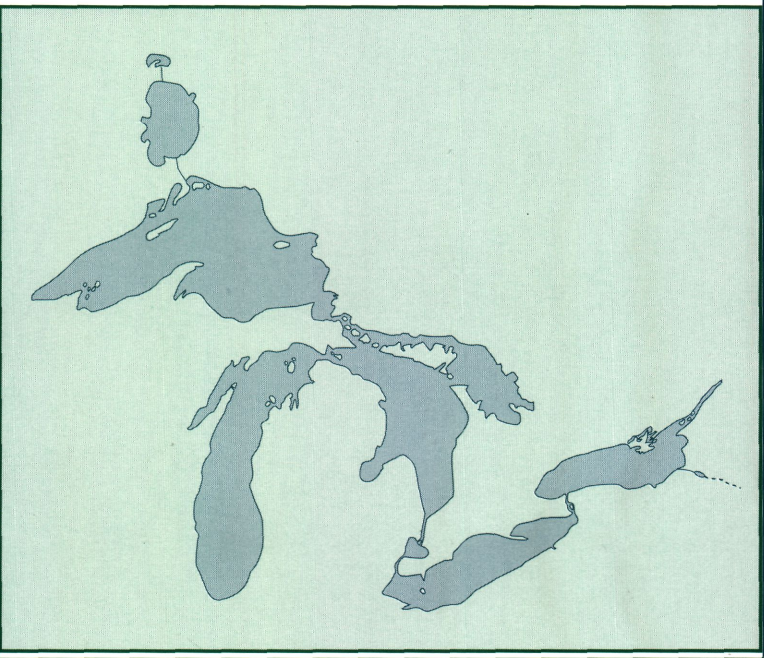
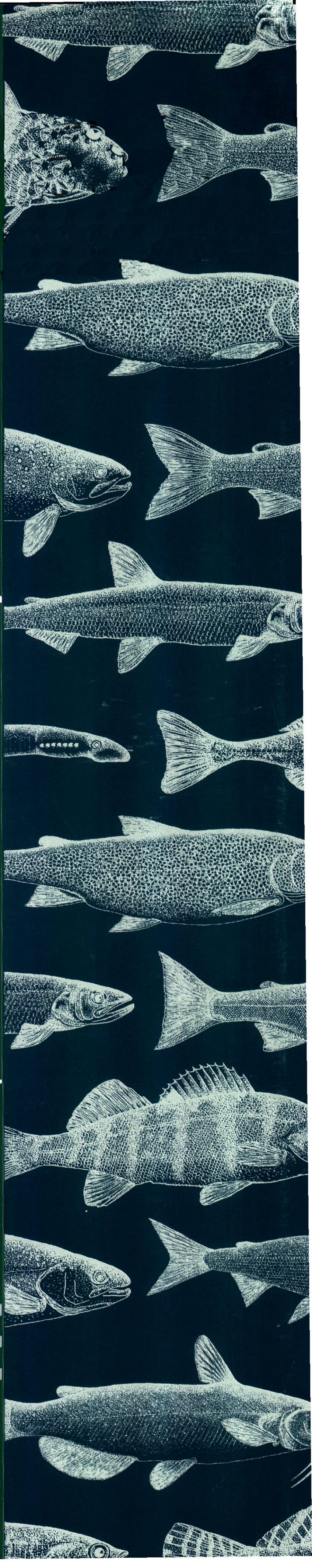
THE LIFE OF THE LAKES

A Guide to the Great Lakes Fishery



The world's greatest freshwater fishery.



Michigan Sea Grant Extension
Michigan State University

The Life of the Lakes

A Guide to the Great Lakes Fishery

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The Life of the Lakes

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Introduction

The Great Lakes—vast, ever-changing waterways — provide a home to one of the world's greatest freshwater fisheries. These Great Lakes fisheries — intricate webs of fish populations, the people who use and enjoy them, and their environments — are important parts of the life of the lakes.

Changes in the life of the lakes reflect the history of the Great Lakes region. Through the history of the **fishery**, we can understand the lifeways of those peoples who have depended directly on the vitality and productivity of the lakes. The story of the **fishery** reflects the story of various impacts on water quality in the Great Lakes. Fishes serve as valuable indicators of environmental change and environmental health, and fish populations have served as early warning signals of poor environmental quality. The quality of Great Lakes fisheries helps us better understand what constitutes quality of life in the Great Lakes region and throughout North America.

These vitally important fisheries and the rest of the life of the lakes are ever changing. The lifeforms in the lakes have changed much since glacial times, only a few thousand years ago. Change continued with the arrival of explorers, traders and settlers, with the increased human populations in the Great Lakes basin and with expanded trade and commerce in the region. These changes affected past fisheries and the fisheries of today and will undoubtedly influence the fisheries of the future.

The voices of early life in and on the lakes still echo from the names of places along the coasts of each of the Great Lakes—Fish Creek, Whitefish Point, Siskiwit ("fat trout") Bay, Menominee, Sturgeon Bay, Fish Point, Salmon River, Troutburg, Bass Island, Pike Bay, Carp River. Today, the influence of Great Lakes fisheries has spread to sport anglers throughout the region, to the visitors and residents who dine on Great Lakes fishes, and to people who look to the life of the lakes to tell of problems or progress with environmental quality.

This publication was designed to accompany the videotape, "The Life of the Lakes: The Great Lakes Fishery." Its purpose is:

1. To describe the current status of the Great Lakes **fishery**;
2. To detail the Great Lakes **fishery** of the past including the social, technological and environmental changes it has faced over time;
3. To discuss fisheries issues expected in the future.

Throughout the text, terms used to describe the Great Lakes **fishery** are shown in bold and appear with definitions in the Glossary (Appendix 2). Detailed information about plants and organisms important in Great Lakes **ecology** appears in species profiles on pages 8, 9, 20, 36 and 37.

"I'd like to think that the fisheries people started out this awareness of the Great Lakes."

Lee Kernan
Wisconsin Department of Natural Resources
from: The Life of the Lakes: The Great Lakes Fishery

Great Lakes Fisheries: The Present

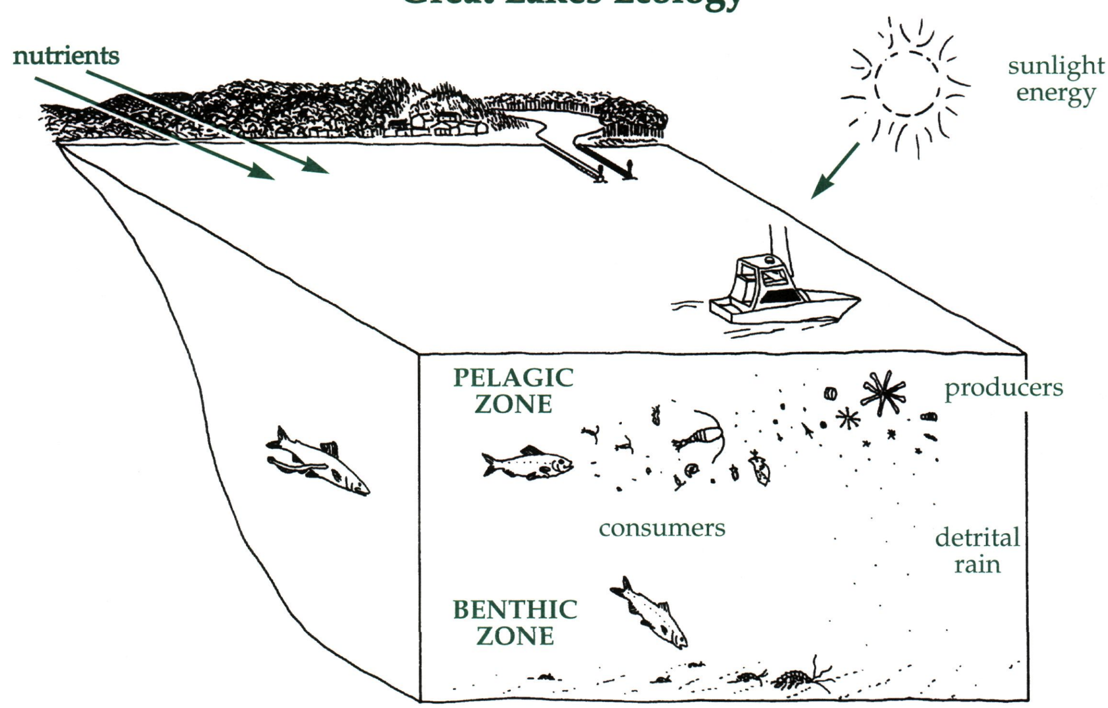
Characteristics of the Great Lakes Important to the Fisheries

The Great Lakes are a relatively young system compared with the world's oceans. The present day lakes were formed between 14,000 and 4,000 years ago, leaving a relatively short time for fishes to evolve or move into the region since the last glaciers retreated. In addition, they have areas that are cold, deep and low in nutrients (a condition called **oligotrophic**), and the northern climate where they are found has a short growing season.

In spite of their harsh surroundings, the Great Lakes are a productive system for a variety of lifeforms. One of the largest surface freshwater systems in the world, their sheer size means that these bodies of water can support an abundance of life. Together, the Great Lakes cover over 94,000 square miles (244,000 square kilometers) of surface area, an area larger than the states of New York, New Jersey, Connecticut, Rhode Island, Massachusetts, Vermont and New Hampshire combined! They contain 6 quadrillion gallons (22.7 quadrillion liters) of freshwater, one-fifth of the world's supply of fresh surface water.

Lifeforms find a variety of subregions within the lakes that vary in temperature, depth, chemical characteristics (such as nutrients), and other physical or biological characteristics. The intricate shorelines of the lakes (including the shores of many islands) total about 11,000 miles (17,700 km). Bays, rocky **reefs** and the sheltered areas around islands provide the shallows that many fishes find necessary at some time in their life cycles. Some of these areas are **eutrophic**, warmer and richer in nutrients than the deeper, colder **oligotrophic** portions of the lakes. Other areas are **mesotrophic**, with moderate amounts of nutrients and biological productivity. Coastal **wetlands** provide valuable **spawning** (breeding) areas for some fishes and nurseries for juvenile (young) fishes. **Wetlands**, with their warm, shallow, nutrient-rich waters support a rich growth of aquatic plants, which in turn harbor small aquatic life. These conditions provide food and shelter for fishes. Waves and currents also may carry nutrients and energy from **wetlands** into offshore areas, enriching them enough to support more life.

Great Lakes Ecology



Streams and rivers drain over 295,000 square miles (767,000 square kilometers) of the heart of North America, forming the Great Lakes **watershed**. These streams and rivers provide areas where some fishes, such as salmon, migrate to **spawn**. Other river-**spawning** fishes include steelhead, rainbow smelt, suckers, lake sturgeon, lake whitefish, white bass and walleye.

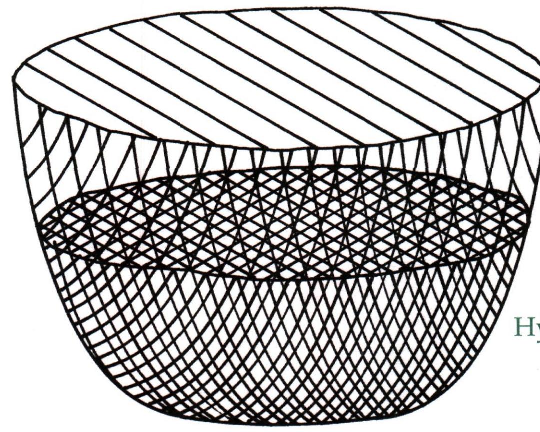
The Great Lakes provide a variety of **habitats**, areas where fishes can find their life requirements such as food, shelter and space. The **littoral** zones are those nearshore (or inshore) areas shallow enough for light to penetrate the water and reach the lake bottom. Like coastal **wetlands**, the **littoral** zones are very valuable for Great Lakes fisheries because they provide areas for **spawning** and feeding. In protected areas, rooted plants provide cover for fishes and other life. The **pelagic** zone is the rest of the open-water area of a lake. Some adult fishes, such as salmon, prefer to spend a large part of their time in this zone. The **benthic** zone is at the bottom of the lakes.

The Great Lakes have a variety of bottom types: muddy, silty, sandy, and rocky or gravelly. Some organisms, called **benthic** organisms, prefer to live in this bottom zone. Here, in the **sediments** or among the different bottom materials, live bacteria which help decompose dead organic material and **detritivores,** small animals which feed on decomposing matter. Some fishes (such as burbot and lake sturgeon) prefer to live in the **benthic** zone, feeding on the small organisms that live there.

Seasonal changes also provide a variety of fish **habitats**. In the summer, portions of all of the lakes have some **thermal stratification**. Underneath a warmer top layer of water called the **epilimnion**, the water is layered like a gelatin dessert with a thin **metalimnion** (layer of greatest temperature drop). The colder, heavier water is located at the bottom (a layer called the **hypolimnion**). Different fishes and the foods they rely on are found in different water layers. Each species of fish has a preferred range of temperatures and other water conditions. Some species, such as salmon and lake trout, are definitely coldwater fishes. Others, such as walleye and perch, are coolwater fishes and do better in waters that are slightly shallower and warmer.

In the fall, as surface waters cool and become heavier, these cool waters sink and a turnover of Great Lakes water occurs. During winter, ice covers some large areas of the shallowest lake (Erie) and the upper three Great Lakes—Superior, Michigan and Huron. In spring, as water is heated by the sun to about 39.2° F (4° C) (the point at which water is densest and heaviest), this water sinks and turnover occurs once again.

Thermal Stratification of a Lake in Summer



Turnover is not uniform across any given lake. Strong winds can play a role in the turnover process, and an early spring can mean early productivity in the lake. Winds also can cause **upwellings**: strong winds can cause warm water at the surface to move laterally so that cold, nutrient-rich water from the deeper layers moves up toward the surface. This variety and mixing is important for fishes, because turnovers and **upwellings** cause oxygen and nutrients to be mixed throughout all layers of the lakes' water.

Since the retreat of the glaciers, the Great Lakes basin has been connected at various times with the Mississippi drainage system or through a variety of outlets to the Atlantic Ocean. All of the basin's original lifeforms evolved in the Great Lakes or invaded from one of three directions: from the Susquehanna River and Hudson River drainages of the Atlantic Coastal Plain, the Mississippi River drainage basin or the Yukon basin of Alaska. In more recent years, species have moved into or out of the lakes through the Erie Canal, the Welland Canal, or the Chicago Sanitary and Ship Canal, or have been intentionally introduced by humans.

Today, 180 species of fishes are found in one or more of the Great Lakes. Lake Erie has the most fish species, while Lake Ontario has more fishes from the Atlantic drainage than any of the other lakes. Lake Superior has half as many fish species as the other lakes, but this northernmost lake has the unique "siskowet," an extremely fatty subspecies of lake trout. Lakes Superior, Ontario and Erie, with an east-west orientation, have more kinds of fishes in their southern tributaries than in their northern streams and rivers. This is probably because many fishes invaded the region from the south, as glaciers melted and the climate of the region warmed. (See pocket insert "Fishes of the Great Lakes" for a full listing of fishes found in the Great Lakes and their

Number of Fish Species Found in the Great Lakes

Basin	# of fish species in lake	# of fish species in tributaries
Erie	99	124
Ontario	95	118
Huron	87	109
Michigan	78	130
Superior	45	71

Source: Underhill, 1986.

tributaries, their **habitats** and whether they were introduced, or are native to the lakes.)

Lakes Ontario and Erie have many fishes in common with each other because they are farther south than the other lakes and are closely connected through the Welland Canal. Lakes Huron and Michigan contain very similar fish species. Because they are at the same elevation and are connected through the Straits of Mackinac, they might be considered as one lake were it not for differences in physical and chemical characteristics. Lake Superior is unique in its collection of fishes. Lakes Superior, Huron and Michigan are commonly known as the upper Great Lakes since they are farther upstream than the other lakes. Each lake's set of fish inhabitants is closely tied to the whole set of living and nonliving lake characteristics — collectively called the **ecosystem**.

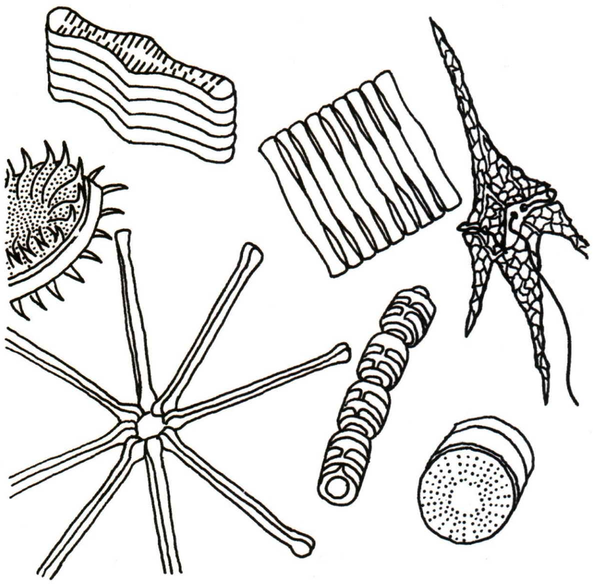
The Life in the Great Lakes

People know that Great Lakes **ecosystems** cannot produce fish in just any place, anytime, in unlimited numbers. Nonliving, or **abiotic** factors (climate, sunlight, temperature, depth, movement of water, nutrient and dissolved oxygen concentrations, shoreline characteristics, and many other factors) work together to affect the amounts and types of plant and animal life that can be supported in the lakes. The study of the interrelationships between organisms and their environment is called **ecology**.

The **food chain** is the chain of organisms which in turn feed on each other and through which energy is passed on from one organism to another. Plants form the base (the first **trophic level**) of the Great Lakes **food chains**. They convert and store the sun's energy and available nutrients into living **biomass**, which is then available to other organisms in the **food chain**. For this reason, plants are called producers. In the Great Lakes, most of these producers are microscopic, floating plants called **phytoplankton**. Examples of **phytoplankton** are **diatoms** – tiny, single-celled plants with hard shells of silica. They may cling to each other in groups or in loose filaments or may cling to underwater objects. Other **phytoplankton** in the Great Lakes are green **algae,** blue-green **algae,** (cyanobacteria), and dinoflagellates (plants with hair-like structures that allow them to move). Peaks in **phytoplankton** growth occur twice a year, the first in spring (mostly **diatoms**), and the second in the fall (**diatoms** and blue-green and green **algae**). These bursts of **phytoplankton** growth are called **algal blooms** and follow spring and fall turnover.

The next **trophic level** is made up of tiny or even microscopic, floating or somewhat mobile animals called **zooplankton**. These are the first level of consumers in the Great Lakes. These animals have a great variety of forms with unique life cycles (see species profile). Types of **zooplankton** commonly found in the Great Lakes include: copepods (such as *Cyclops*) which make up the bulk of the Great Lakes **zooplankton**, protozoans (microscopic one-celled animals such as amoebas and paramecium) which are the most numerous of **zooplankton**, cladocerans ("water fleas"—*Daphnia*) which are numerous in the summer months, amphipods (better known as "sideswimmers"), and rotifers. Large **zooplankton** become most numerous in the summer, while small **zooplankton** are abundant in the spring and fall. Their numbers are influenced by such things as early spring arrival, winds, turnovers, **upwellings** and productivity of the water. Many species of **zooplankton** migrate several meters (many thousands of times their body length) up and down in the water daily. These movements are affected by light levels, season, and temperature.

The next **trophic level** consists of **macroinvertebrates** (larger animals lacking backbones). Different types of these animals live in deep areas and shallow areas of the Great Lakes. Deepwater life is dominated by two unique small animals: *Diporeia* spp. (an amphipod or "sideswimmer" sometimes mistakenly called a freshwater shrimp) and opossum shrimp (*Mysis oculata relicta*). Also found in deep waters are oligochaetes (freshwater worms) and larvae of midges (chironomids). The small animals found in shallow, protected waters are similar to those found in cold, inland lakes — leeches, clams, snails, and larvae of mayflies and caddisflies. The average density of these small, burrowing animals may reach hundreds of animals per square meter. Some areas of the Great Lakes may be even more productive with thousands of small animals per square meter.



Phytoplankton

Zooplankton

Phytoplankton

(diatoms, green algae, blue-green bacteria, protists)

Description: microscopic to visible free-swimming plants; found to depths where light can penetrate water. *(Note: Not drawn to scale; scales range from 10,000 to 20,000 times life size.)*

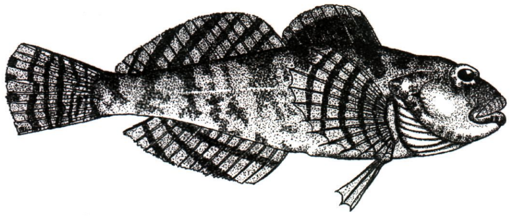
Zooplankton

Description: microscopic to visible animals which are free-swimming; includes a variety of types of animals. *(Note: Not drawn to scale; scales range from 5 to 1,000 times life size.)*

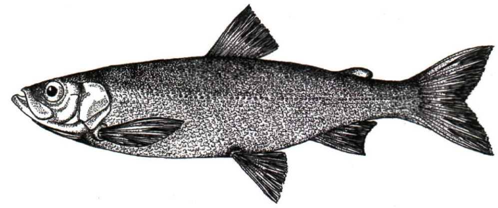
- Crustaceans:
  - Water fleas (cladocerans) – body has hard shell; branched swimming antennae; large eye
  - Copepods (e.g., *Cyclops*) – cylinder shaped body; long, segmented swimming antennae
  - Opposum shrimp (mysids) – 10 pair of jointed legs; looks like miniature crayfish; stalked eyes
- Rotifers: rotating hairlike cilia at front of body
- Protozoans: single-celled animals such as amoebas, paramecium

Adult Diet: mostly omnivorous, eating algae, **detritus,** rotifers, protozoa, other crustaceans; **predators** which grasp their prey include *Cyclops* and *Leptodora* (a type of water flea). Opposum shrimp, daphnia (a water flea), and rotifers sweep food to their mouths and strain it from the water.

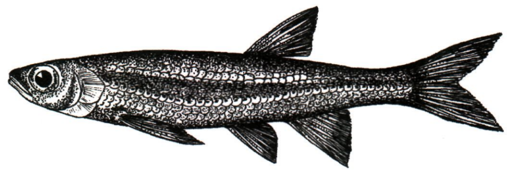
Habitat/Behavior: mostly **pelagic**, found throughout Great Lakes. Make vertical migrations daily which vary with light levels, season, and age and sex of the individual animal. Most migrate up as darkness sets in and return to deep at dawn. Some species do reverse migration or twilight (at dusk and dawn) migration. Opposum shrimp also make these migrations, but may be considered more **benthic** than other **zooplankton** since they are more often found near the bottom during the day and are found in the **hypolimnion** during the summer. Opposum shrimp reproduce in fall, winter and early spring, then carry their eggs and young in a brood pouch for up to 3 months; young leave the pouch when about 3-4 mm long. Opposum shrimp are an important food source for trout, whitefish and chubs (ciscoes).



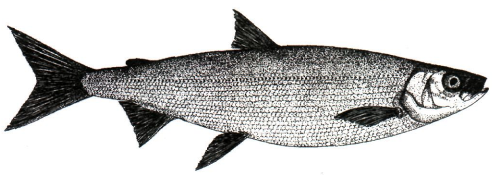
Sculpins



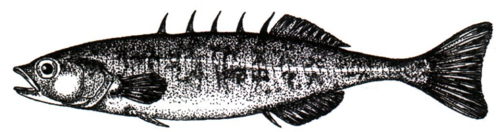
Bloater



Emerald shiner



Lake herring



Sticklebacks

Forage Fishes

Description: small fishes which serve as food for larger fishes

Examples: sculpins — 7 in. or less; large head, stout body; large and fanlike pectoral fins; pelvic fins (usually with one spine) under pectoral fins
bloater — 8 -10 in.; long, deep-bodied fish with adipose fin
lake herring — 8 -12 in.; similar to bloater but with more gill rakers
sticklebacks —2-4 in.; small, thin fish; dorsal spines unconnected by fin tissues
emerald shiner — 2-3 in.; silvery, iridescent body

Adult Diet: mostly **plankton**, insect larvae, some benthos; larger species may take smaller fishes

Habitat/Behavior: The usefulness of **forage fishes** to **predators** depends on their size and on their location; any fish small enough to fit into a **predator** fish's mouth is a potential forage fish! There were many species of native **forage fishes**, some unique to the Great Lakes; they were found virtually throughout the lakes until commercial fishing removed some of the larger species of chubs (ciscoes).

Sculpins—**benthic** and **littoral**; some **spawn** in spring, others in late summer or early fall; mottled and slimy sculpins establish nests under rocks or other debris and deposit eggs on the ceiling of the nest. Deepwater sculpins eat mainly midge larvae and *Diporeia* spp. Spoonhead sculpins eat planktonic crustaceans in deep-water areas, and aquatic insect larvae inshore. Other sculpins eat mainly aquatic insect larvae and crayfish.

Bloater —**pelagic** and **benthic**; **spawn** in February through March. Eat mainly **zooplankton**, particularly *Mysis, Diporeia* spp.

Lake herring — **pelagic**; gather in large schools to **spawn** in late November or early December. Mainly a **plankton** feeder eating *Mysis, Diporeia* spp.

Sticklebacks —**littoral** and benthic; **spawn** in spring or summer. Some build nest of sticks or weeds. Eat aquatic insects, planktonic crustaceans.

Emerald shiner — mainly **pelagic**; **spawn** in summer. Form schools offshore in summer, move inshore in fall, and in spring; spend days in deep water and move to surface at night. Feed mainly on **plankton** and algae, and eat some midge larvae.

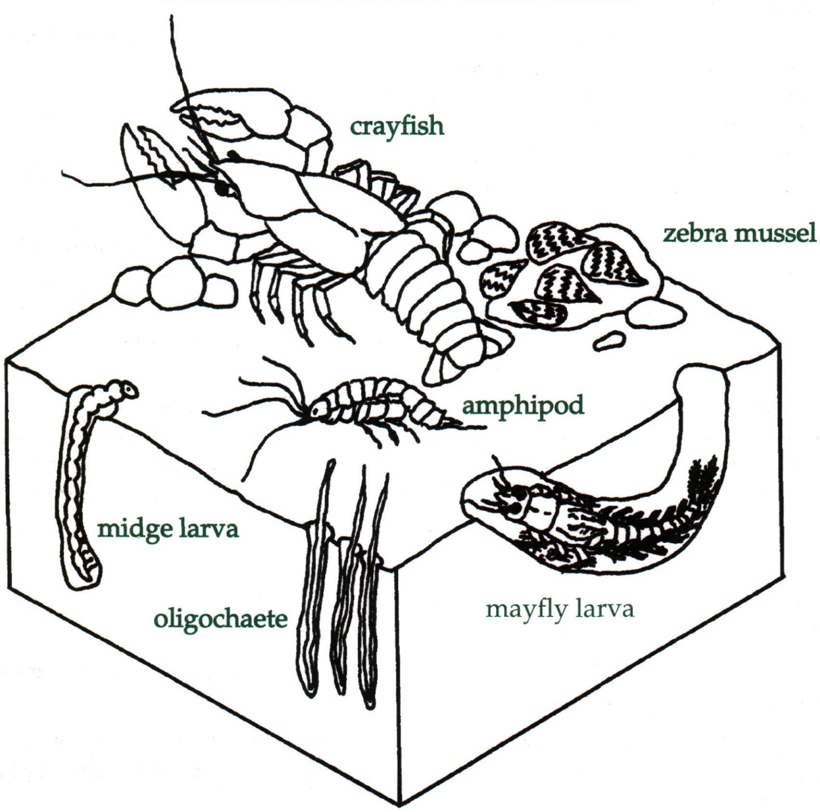
Together macroinvertebrates provide the basis for fishes at the next **trophic levels** in Great Lakes **ecosystems**. Some fishes feed mainly on **zooplankton**; these fishes (such as alewife, various shiners, and lake herring) are called **planktivorous** (**plankton**-eating) fishes. The alewife and other **planktivorous** fishes have specialized structures, called gill rakers, which sift out food as water passes through their gills. Other fishes, such as lake trout, feed on a combination of **plankton**, **macroinvertebrates**, and fishes. Generally, the juveniles of large or medium-sized Great Lakes fishes (such as salmon and yellow perch) feed mostly on **zooplankton** and **macroinvertebrates** until they grow large enough to eat small fish.

Small fishes, in turn, provide food for larger fish. These small fishes, such as bloaters, lake herring, sculpins, shiners, alewife, smelt and juveniles of other species, are called **forage fishes**. Fishes which eat other fish are called **piscivorous**.

Consumers of Great Lakes fishes include humans, birds (such as bald eagles, herons, osprey, cormorants, mergansers and loons) and mammals (such as mink and river otters). It is important to remember that the chain does not end with these **consumers**. As all organisms die, whether they are the larger animals or the microscopic **plankton**, decomposers such as bacteria and fungi begin their work. As they feed on dead material **(detritus)**, organic materials are broken down and nutrients become available to the **producers** (plants) at the start of the **food chain**. Some of these organisms are found in the **sediment** at the bottom of the lakes, even in deep regions. For example, *Diporeia* spp. and oligochaetes burrow into **sediments** and feed on **detritus**. Other small organisms (such as rotifers) feed in midwater on the **detrital rain**, the dead **algae** and **zooplankton** that sink down from upper layers of water. These decomposers and **detritivores** play an important role in the Great Lakes. Their recycling of nutrients allows even deep areas of the Great Lakes to be productive and to support life.

Each link in the Great Lakes **food chain** may strongly influence other links. For example, **zooplankton** may play a role in grazing, or cropping **phytoplankton** growth. In turn, fish can affect the size and species composition of **zooplankton** by visually searching out and eating larger **plankton**. In turn, the size of **zooplankton** and **forage fishes**

Benthic Life in the Great Lakes



These organisms are scavengers and detritivores. Not drawn to scale; scales range from 1/2 life size to 10 times life size.

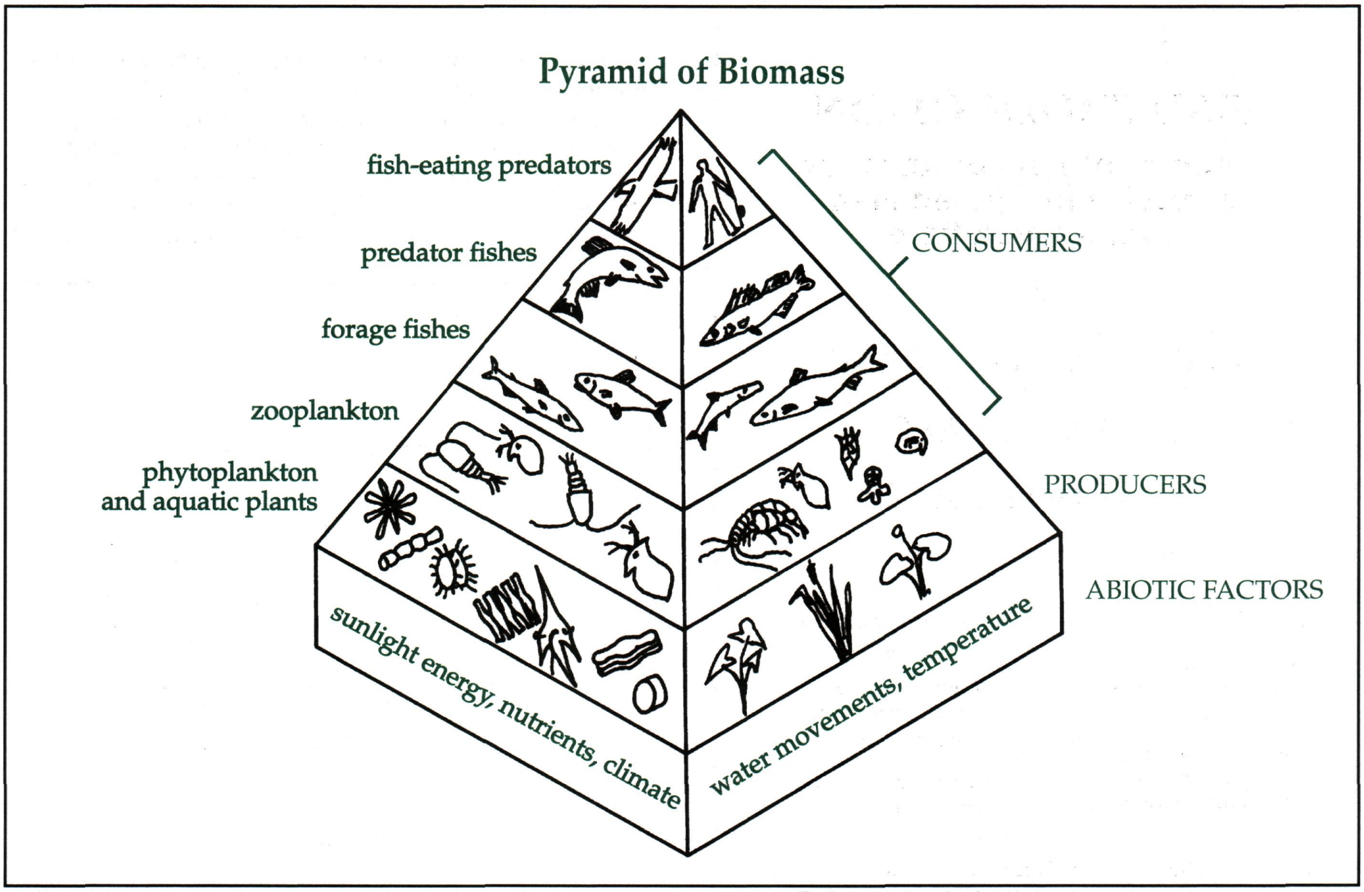
eaten can influence the **predators'** growth rates. When a new, **exotic** species such as the alewife arrives in the Great Lakes, effects are felt both up and down the **food chain**.

The lakes can support only a limited amount of lifeforms. The **carrying capacity** or productivity of a part of a lake is determined by a variety of factors acting collectively. The number and bulk of top level **consumers** an area can support is always less than the amount of organisms under that level. At each **trophic level**, some energy is used by the organisms for growth, reproduction or movement, and some energy is lost in the form of heat. This means that at each higher level, less energy is available for use at that level, so each level supports fewer organisms.

In reality, life in the Great Lakes does not exist as a simple **food chain**. Many organisms feed on more than one type of food; in fact, some can readily switch food types if a regular food supply is depleted. A better picture of the complex **ecology** of the Great Lakes is shown by a **food web**.

The Great Lakes **food web** is complex and ever-changing. Some of its members have arrived relatively recently in the Great Lakes, causing significant changes in the **food web**. The alewife, smelt, sea lamprey and Pacific salmon are examples of such **exotic** species. Some members, over time, have declined in numbers due to overfishing, poor environmental quality, or parasitism by the sea lamprey. Atlantic salmon in Lake Ontario probably declined because of **habitat** loss from early logging and dam building, lake sturgeon because of damming and overfishing (and its low reproductive rate), and lake trout because of sea lamprey predation and other factors such as **habitat** degradation, overfishing and decline of its foods. When top **predators** such as lake trout disappear, the effects are noticed throughout the rest of the **food web**. Other members of the web have been intentionally introduced by fisheries managers, both to assist in limiting numbers of other organisms and to provide fishing opportunities. For example, Pacific salmon (chinook salmon and coho salmon) were introduced to reduce alewife populations and to provide sportfishing.

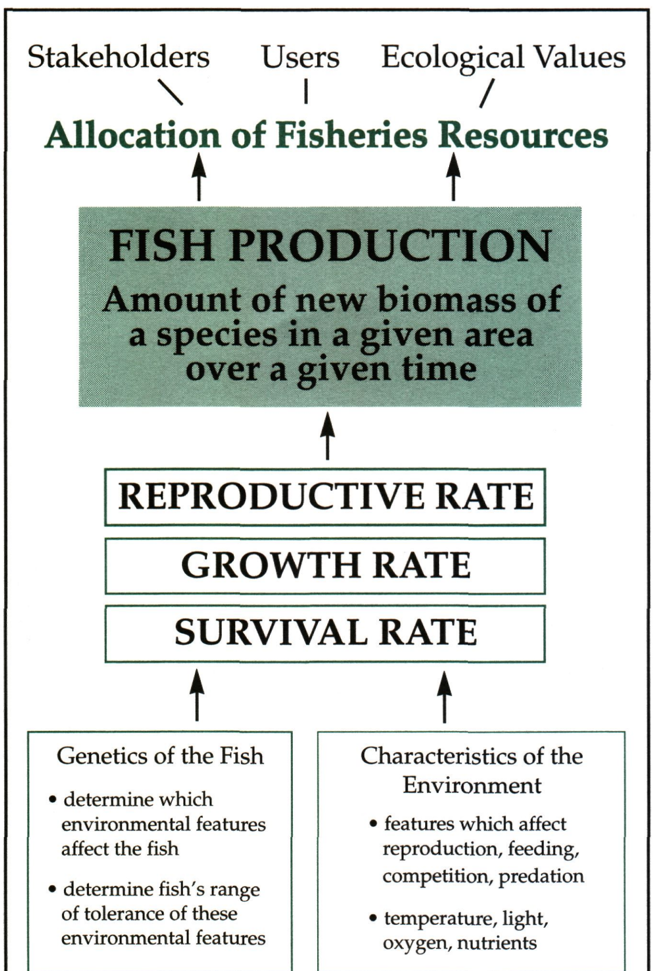
Understanding Great Lakes **ecology** includes studying the life cycles and **habitats** of various organisms. Nearly all Great Lakes fishes can be found in shallow water during part of their life cycles. Many species use shallow waters as **spawning habitat** either in the spring or the fall. Spring



spawners include lake sturgeon, various suckers, channel catfish, bullheads, yellow perch, walleye, northern pike, and smallmouth bass. Fall **spawning** fishes include lake trout, lake whitefish, menominee whitefish, lake herring, chinook and coho salmon.

Fish species prefer certain **habitat** types for **spawning** and for early development of their **fry**, or newly hatched young. Some, such as northern pike, prefer **wetlands** with aquatic vegetation; others such as lake whitefish, prefer shallow **reefs** which provide rich areas for food items and some structure (cover) to retain the eggs and in which the **fry** can hide from **predators**. Much remains to be learned about the early-life histories of Great Lakes fishes; early-life histories of fishes provide an active area of research today.

Whatever their course of development, the success of fishes depends on the match between the organisms and their environment. The genetics of the species and the individual fish help to determine what environmental features are important to that fish. In addition, genetics determine the range of tolerance of a particular fish. For example, lake trout are genetically adapted to cold, clear, highly oxygenated waters; they grow best in waters around 10.5° C (50.9° F), and temperature extremes may be deadly. The genetics of a fish, combined with the actual characteristics of the fish's environment, work together to affect that fish's reproduction, growth and survival. Some groups of fishes (for example lake sturgeon) have slower reproductive rates than others; for most fishes, growth rates are greatly affected by the quality (and/or size) of food sources and by water temperatures. The result of all of these factors is **fish production**, the amount of new **biomass** of a given species in a particular area over a period of time.

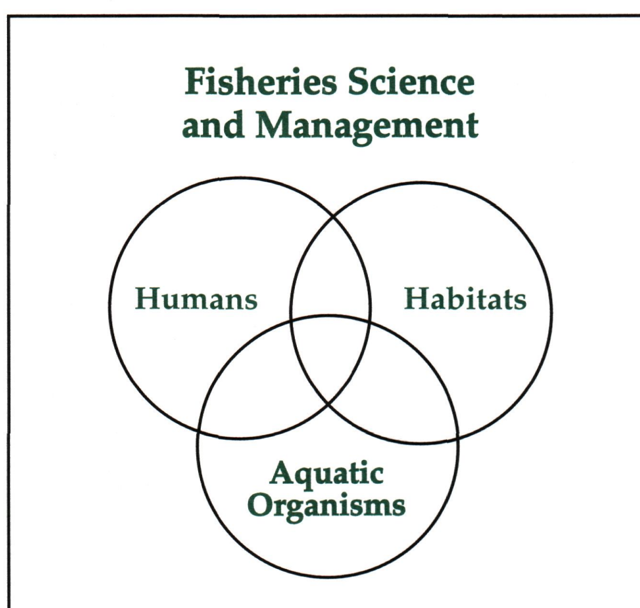


Source: W. W. Taylor, MSU Dept. of Fisheries & Wildlife.

Learning about this web of life in the Great Lakes is crucial to understanding the history of its fisheries, current fisheries issues, and environmental quality issues. Understanding the biological basis for these fisheries is also important when decisions are made about allocating or dividing fisheries resources among various resource-user groups. Today, fisheries scientists and managers, as well as many other professionals and citizens, are involved in making such decisions.

Fisheries Science and Management

Fisheries science is the scientific study of fish and aquatic (water-related) resources. This science involves understanding the structure, dynamics (or changes), and interactions of **habitat**, aquatic organisms and humans in order to achieve certain goals set by humans. Specific studies follow the **scientific method**, a systematic way of gathering and evaluating



information by posing specific research questions (hypotheses), making observations, compiling results and interpreting findings. Many different types of scientists work with fisheries scientists. These include **limnologists** (who study freshwater **ecosystems** much as oceanographers study marine systems), water-quality analysts, toxicologists, hazardous-waste scientists, biologists, land-use specialists, geologists, geneticists, and social scientists.

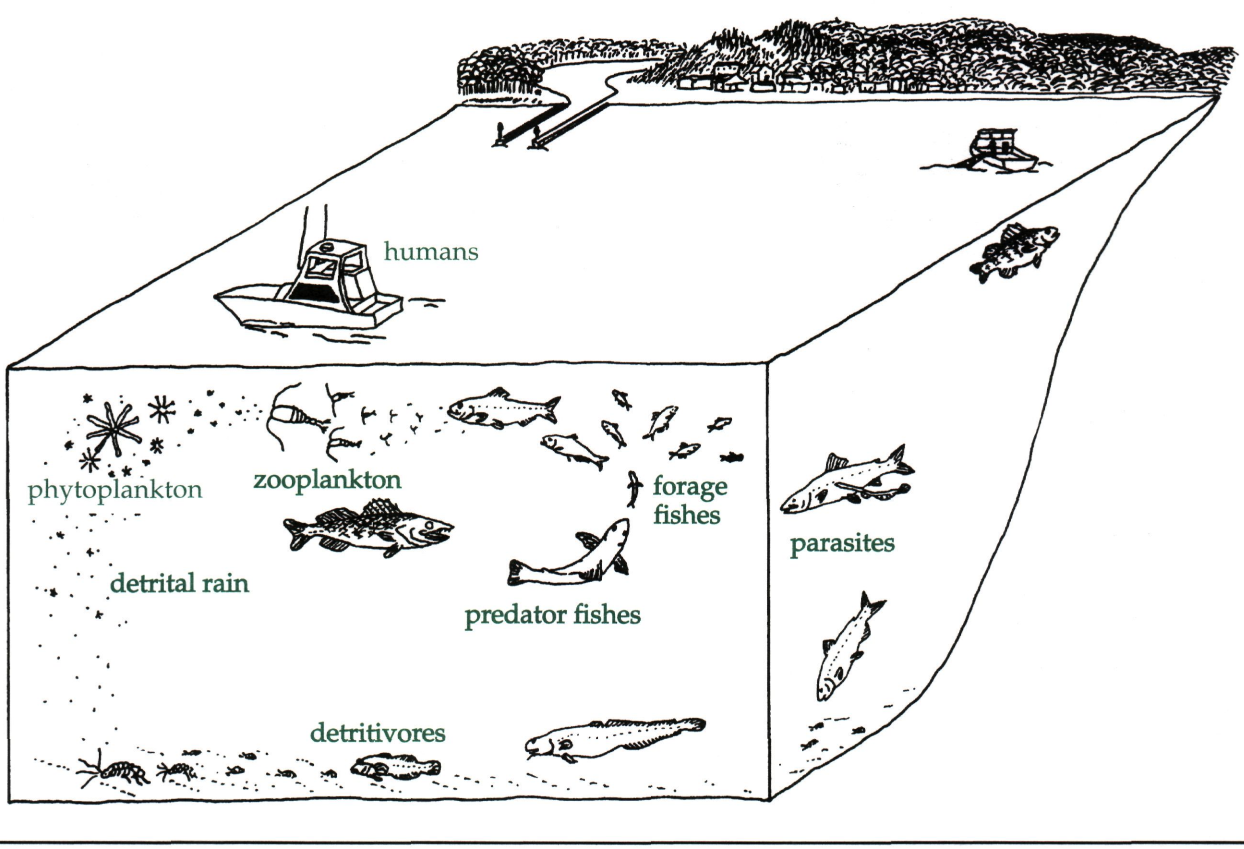
Fisheries management is a branch of **fisheries science**. **Fisheries management** is the translation of information about people, aquatic populations, and habitats into efforts to reach the goals humans desire for particular aquatic populations or **ecosystems**. (For a list of Great Lakes region fisheries-related agencies and organizations, see Appendix 1)

Great Lakes fishes are **common property resources**, resources owned not by individuals but by everyone. State, provincial, federal and Native American tribal agencies are responsible for caring for these resources on the public's behalf, keeping human and resource needs in mind. These agencies are also responsible for allocating these resources, dividing them among resource-user groups. In the U.S., states and tribes have the primary responsibility for management. Because of this complexity, both in the biological and in the human systems in the Great Lakes region, the potential for conflict is great, as is the opportunity to cooperate to solve complicated fisheries issues.

Fisheries management today involves all of the region's fisheries stakeholders. To apply the most current scientific information to decision-making, Great Lakes scientists, fisheries managers and representatives of many organizations come together through two commissions (the Great Lakes Fishery Commission and the International Joint Commission) as well as through professional societies such as the American Fisheries Society (AFS), the Society of Environmental Toxicology and Chemistry (SETAC), and the International Association for Great Lakes Research (IAGLR).

Many organizations are partners with fisheries managers in making decisions about Great Lakes fisheries. Tribal fishers have organizations including the Great Lakes Indian Fish and Wildlife Commission and the Chippewa-Ottawa Treaty Fishery Management Authority. These groups take part and lead efforts in fisheries resource planning, **habitat** improvement, law enforcement, and

Great Lakes Food Web



stocking. State and provincial licensed commercial fishermen also have organizations, as do charter-fishing operators. Commercial and tribal fishers and charter operators help collect data and keep records about fish resources to assist resource management agencies.

Sport anglers have helped manage Great Lakes fisheries for a long time. Concerns about declining fish populations and citizen interest in Great Lakes fisheries led to the formation of fishing and environmental organizations such as Trout Unlimited, the Michigan Steelhead and Salmon Fishermen's Association, the Great Lakes Sport Fishing Council, Michigan United Conservation Clubs and many others throughout the region. Today, these organizations cooperate with fisheries agencies in a variety of resource management activities such as artificial **reef** and **habitat** improvement projects, in hatchery and pen-rearing projects and in raising funds to sponsor fisheries research. Some anglers also volunteer their time for fisheries research and collecting data or responding to surveys to help management agencies.

SPORT FISH RESTORATION

Your purchase
of fishing equipment
and motorboat fuels supports
Sport Fish Restoration and
boating access facilities

Funding for **fisheries management** comes from several sources. About one-third of the funds come from sportfishing licenses, while about half is from governmental general funds from states, the Province of Ontario, and the U.S. and Canada. Another portion is from federal excise taxes on fishing equipment and taxes on motorboat gasoline. The excise taxes are collected under the Federal Aid in Sport Fish Restoration Program (through what is commonly called the Wallop-Breaux Trust Fund). Over $43 million in Wallop-Breaux revenues was returned to Great Lakes states in 1991 for their **fisheries management** programs. Altogether, tens of millions of dollars are spent on Great Lakes **fisheries management** each year. Hundreds of millions of dollars are also spent each year on managing the entire Great Lakes basin (for issues such as water quality that benefit fisheries directly or indirectly).

Fisheries

A **fishery** is defined as the complex interactions between a fish population(s) being used, the humans using it, and the environment of each. Examples of fisheries include: the sport **fishery** (all game species of fishes, their **habitats**, and their users), the commercial **fishery** (commercial species such as lake whitefish and others, their aquatic environments, and those who harvest them), the tribal **fishery** (species caught by federally recognized tribal fishermen, native peoples, and the areas they fish as a result of treaties), and a small subsistence **fishery** (species caught as supplementary food, their **habitats**, and the people who rely on them). Today, the diverse Great Lakes fisheries provide us a wealth of values:

- a source of protein with less fat and fewer calories than other meats;
- economic values, through the commercial-fishing enterprises in the region and to communities through sportfishing and tourism industries;
- social values through fishing or observing fish while diving, membership in fishing organizations, or attendance at social events (such as fishing festivals) sponsored by shoreline communities;
- historical and cultural values, such as helping commercial fishing families (both state- and tribal-licensed) maintain a way of life in some ways similar to the lives of their ancestors or the values of visiting or seeing a historic fishing village or learning about our fisheries history in the Great Lakes;
- ecological values, such as helping people learn about **ecosystems** and their processes and helping monitor the quality of aquatic environments.

The major fisheries in the Great Lakes are sport fisheries and commercial fisheries (including tribal fisheries). These fisheries have some similarities. Charter fishing is a commercial enterprise catering to sport anglers (or as one captain has said, "an entertainment business"). Charter fishing operators, like commercial fishermen, are concerned with markets for their services and with the quality of fish and fishing. Commercial fishermen, like charter operators, influence tourism in some areas; tourists dine on fresh fish in coastal communities and may visit the old fishing villages (such as Fishtown in Leland, Michigan) that remain. No matter the similarities or differences, a variety of stakeholders exists for Great Lakes fisheries. And the stakes are great! An estimate of the total economic impact of the sport and food **fishery** on the Great Lakes regional economy is $2.3 to 4.3 billion per year (in 1985 U.S. dollars).

Sportfishing

The size, scope and importance of sportfishing in the Great Lakes today are tremendous. Some fisheries managers say that the recovery of the fisheries resource from its low days in the 1960s to the sport **fishery** of the early to mid-1980s was nothing short of a resource management miracle. Sportfishing is important to some smaller coastal communities that cater to tourists, recreational boaters and charter-fishing businesses. Estimates place the annual Great Lakes sportfishing effort at about 25 million days spent angling per year by U.S. anglers (1991) and over 14 million days angling per year by Canadians (1985). Economists estimate that the annual economic impact of sportfishing within the Great lakes region is about $4 billion (U.S. dollars). Anglers spent about $2 billion per year for bait, tackle, food, gasoline, boats, and charter services. (About $1.7 billion was spent in the U.S. and $290 million in Canada-[U.S. dollars].)

Where does all of this sportfishing occur? The most recent data available for the region were collected in national surveys conducted by both the U.S. and Canada. These surveys, conducted approximately every five years, indicate that sport fishing is most popular on Lake Erie and Lake Michigan. These two lakes had both the greatest number of anglers, and the highest angling effort (number of days spent angling). Within the U.S., the states of Michigan and Ohio had the most anglers and the most days spent angling.

By far, the most popular fish species sought by U.S. anglers in the Great Lakes region in 1991 were walleye and yellow perch. In the U.S. in 1991, nearly one million anglers went perch fishing, spending a little over 8 million days seeking this fish. In Canada, yellow perch was the fish most frequently caught by sport anglers throughout the basin. Another popular sport fish was the walleye; the walleye was the most common sport fish taken in the Canadian waters of Lake St. Clair in 1985. Walleye was also a popular fish in U.S. waters in terms of days spent seeking it in 1991, with over 1 million anglers spending over 9.4 million days seeking these fish. Other popular sport fish include the salmon species and lake trout. Over 721,000 U.S. anglers sought salmon in 1991. Most salmon within

Number of U.S. Anglers Fishing and Days Spent Angling on Each of the Great Lakes and Connecting Waters in 1991

LOCATION	# U.S. ANGLERS	# DAYS SPENT BY U.S. ANGLERS
Lake Ontario	298,000	2,394,000
Lake Erie	905,000	7.082,000
Lake Huron	230,000	2,113,000
Lake Michigan	864,000	5,090,000
Lake Superior	114,000	883,000
Lake St. Clair	118,000	1,658,000
St. Lawrence River	31,000	218,000
Connecting waters*	260,000	3,021,000
Tributaries**	148,000	1,616,000
TOTALS	2,552,000	25,225,000

(Detail will not add to total due to multiple responses.)

*Connecting waters include St. Clair River, St. Marys River system, Detroit River, Niagara River.

**Includes fishing on tributaries for smelt, salmon and steelhead.

Source: U.S. Dept. of Interior, Fish & Wildlife Service and U.S. Dept. of Commerce, 1993.

Number of Canadian Anglers Fishing and Days Spent Angling on Each of the Great Lakes and Connecting Waters in 1985

LOCATION	# CANADIAN ANGLERS	# DAYS SPENT BY CANADIAN ANGLERS
Lake Ontario	298,812	3,745,579
Lake Erie	171,683	1,949,822
Lake Huron	443,118	5,183,058
Lake Superior	90,091	967,057
Lake St. Clair	57,625	952,209
St. Lawrence River	82,787	1,220,0114
Connecting waters*	43,247	607,361
TOTALS	997,656	14,625,100

(Detail will not add to total due to multiple responses.)

*Connecting waters include St. Clair River, St. Marys River system, Detroit River, Niagara River.

Source: Dept. of Fisheries and Oceans, Canada, 1989.

Popularity of Fish Species for U.S. Anglers on the Great Lakes and Connecting Waters in 1991

FISHES	# U.S. ANGLERS SEEKING FISHES	# DAYS SPENT BY U.S. ANGLERS
Walleye and sauger	1,028,000	9,489,000
Yellow perch	983,000	8,170,000
Salmon	721,000	4,622,000
Largemouth and smallmouth bass	526,000	4,369,000
Lake trout	482,000	2,980,000
Steelhead	289,000	2,444,000
Other trout	276,000	2,280,000
Northern pike, pickerel, muskie	213,000	2,318,000

Source: U.S. Dept. of Interior, Fish & Wildlife Service and U.S. Dept. of Commerce, 1993.

Canadian waters of the lakes were caught in Lake Ontario, while the most lake trout within Canadian waters were taken in Lake Huron. In spite of the large numbers of lake trout taken in the Canadian waters of Lake Huron, the most frequently caught fishes there were smelt and perch. Smelt are also taken in large numbers throughout the region; most smelt are caught with dipnets and seines (Canada) during spring **spawning** runs. The methods by which anglers take other sport fishes vary widely from area to area within the lakes and include pier fishing, boat fishing, wading, and icefishing.

More than 2.5 million U.S. anglers spent more than 25 million days fishing on the Great Lakes in 1991. These U.S. anglers made a total of nearly 20.5 million angling trips; in 1991, they spent $1.3 billion for fishing on the Great Lakes.

The lifestyles of sport anglers and the impact they have on the resource are important throughout the Great Lakes region. The sportfishing industry has brought new life to many coastal towns. Some communities have developed their shorelines with sportfishing clients in mind. Other communities have developed popular fishing festivals and sportfishing tournaments to attract visitors and to celebrate their Great Lakes fisheries resource heritage. Family fishing traditions may include pier fishing, taking special fishing trips within the region, or focusing on particular **spawning** runs which occur at various times of the year. The steelhead runs in spring, fall and winter draw anglers to traditional, favorite fishing areas on tributaries. Likewise, **spawning** runs of suckers, salmon, smelt and other fishes offer predictable opportunities for fishing with family and friends.

Popularity of Fish Species by Numbers of Fishes Caught by Canadian Anglers on the Great Lakes and Connecting Waters in 1985

FISHES	NUMBER CAUGHT BY CANADIAN ANGLERS
Perch	18,128,013
Smelt	13,458,485
Panfishes	6,169,686
Smallmouth bass	5,912,005
Walleye	5,470,093

Source: Dept. of Fisheries and Oceans, Canada, 1989.

The Great Lakes region has taken on a sportfishing identity to people considering travel here. Bait and tackle shops and other support industries are commonplace in coastal communities. Tourism has been touted by states throughout the region as an economic development alternative to heavy industry. Some fishing equipment, such as the downrigger, (a weighted device which allows a lure to be trolled at a given depth) was developed in this region to meet the needs of Great Lakes anglers.

The charter fishing industry grew tremendously in the region during the 1970s and 1980s. The number of charter fishing boats in the U.S. grew from several hundred boats in 1975 to more than 3,000 boats in 1988. Trip expenditures by charter fishing anglers peaked in the late 1980s, with Michigan

Number of Anglers and Days Spent Angling by U.S. Anglers on Great Lakes and Connecting Waters by State in 1991

STATE	# U.S. ANGLERS	# DAYS SPENT BY U.S. ANGLERS
Illinois	238,000	1,382.000
Indiana	97,000	573,000
Michigan	886,000	11,060,000
Minnesota	52,000	303,000
New York	458,000	4,426,000
Ohio	629,000	4,602,000
Pennsylvania	85,000	629,000
Wisconsin	301,000	2,353,000

Source: U.S. Dept. of Interior, Fish & Wildlife Service and U.S. Dept. of Commerce, 1993.

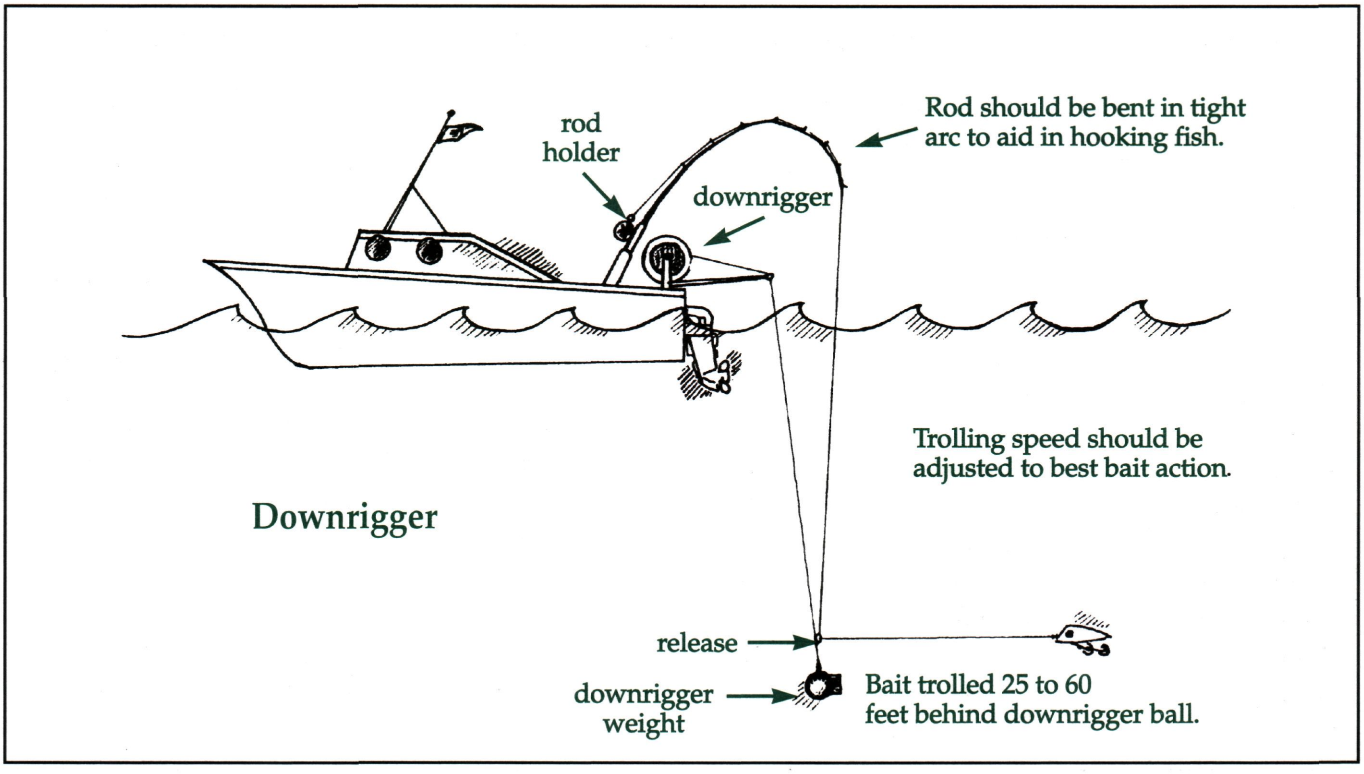
charter anglers alone spending a total of over $59 million. Recently, however, these charter fishing industries and recreational fishing as a whole have suffered major declines in some areas mainly due to decreases in chinook salmon **stocks**. Factors which may have contributed to this sportfishing decline include bacterial kidney disease (BKD) in salmon, general economic downturns, declines in other fish populations, including the prey species of salmon, and concern over **contaminants** in fishes.

Researchers and managers are just beginning to understand the preferences and interests of Great Lakes anglers. This understanding of angler attitudes is necessary to help predict the future demand for fisheries resources and to allocate the fisheries resources available today. While some are concerned that urbanization and other factors may cause fewer people to participate in fishing in the future, others are concerned about too much angling pressure in some areas. Catch-and-release fishing has recently increased in popularity in the Great Lakes region; some anglers gain satisfaction from releasing their prized catch back into the water. Whether to keep or release a fish is considered an ethical question. In the future, such questions of angler ethics will become more important in maintaining a quality Great Lakes sport **fishery**.

Commercial and Treaty Fishing

The contribution of the state/provincial-licensed commercial and treaty fisheries in the Great Lakes region today is substantial. Many people in the basin depend on commercial fishing for their livelihood. About 9,000 worker-years were spent in the commercial Great Lakes food **fishery** in 1985. The value of the commercial **fishery** is substantial; in 1985 the estimated total **landed value** of the Great Lakes commercial **fishery** was $41 million ($15 million in the U.S. and $26 million in Canada) (U.S. dollars). **Landed value** is the price paid to fishermen, before processing, wholesaling or retailing the fish. The final sales value for Great Lakes fish in that year however was $133 million ($49 million in the U.S. and $84 million in Canada)(U.S. dollars). Estimated total catch by commercial state-licensed and treaty-licensed fishermen in 1991 was more than 81 million pounds (36.7 million kilograms). **Landed value** was estimated at U.S. $22.5 million for the fish harvested from U.S. waters and CDN $37.1 million for fish taken in Canadian waters.

The species of fish taken in the largest quantities varies by lake, by state or province and by country. In Lake Superior over half of the commercial harvest (by weight) is lake whitefish. Other important species in Lake Superior are lake herring and lake trout (lean and fat [siskowet] forms). In Lake Huron, lake whitefish comprise about half of the total commercial catch for both U.S. and Canadian



Estimated Worker-Years Attributable to the Great Lakes Food Fishery in 1985

OCCUPATIONS	WORKER-YEARS IN THE U.S.	WORKER-YEARS IN CANADA	TOTAL WORKER-YEARS IN THE GREAT LAKES FOOD FISHERY
Fishing	300	500	800
Processing & Wholesaling	1,900	3,300	5,200
Secondary	1,100	1,900	3,000
TOTALS	**3,300**	**5,700**	**9,000**

Source: Talhelm, 1988.

1991 Catch and Landed Value of Fisheries in the Great Lakes

LAKE	U.S. WATERS		CANADIAN WATERS		ALL GREAT LAKES WATERS
	Total catch (lb.)	Total value (U.S. dollars)	Total catch (lb.)	Total value (Canadian dollars)	Total catch (lb.)
Ontario	232,551	184,630	1,212,728	1,036,489	1,445,279
Erie	5,793,590	3,009,708	40,620,666	28,198,935	46,414,256
Huron	4,747,267	3,413,640	6,378,861	6,992,415	11,126,128
Michigan	17,813,663	13,667,898	—	—	17,813,663
Superior	2,877,240	2,187,020	1,648,681	851,004	4,525,921
TOTALS	**31,464,311**	**22,462,896**	**49,860,936**	**37,078,843**	**81,325,247***

*Total dollar value for catch from all Great Lakes waters is not summed due to fluctuations in U.S. - Canada exchange rates.
Sources: U.S. Fish & Wildlife Service; Ontario Ministry of Natural Resources.

1991 Commercial Catch of Various Species of Fish in U.S. and Canadian Waters of the Great Lakes

SPECIES	U.S. WATERS		CANADIAN WATERS		ALL GREAT LAKES WATERS
	Total catch (lb.)	Total value (U.S. dollars)	Total catch (lb.)	Total value (Canadian dollars)	Total catch (lb.)
Lake whitefish	10,147,729	9,044,929	4,936,706	5,059,193	15,084,435
Yellow perch	3,389,500	6,641,415	5,408,194	11,509,884	8,797,694
Chubs	3,913,231	1,965,686	1,221,500	1,014,307	5,134,731
Lake trout	312,186	156,872	306,454	252,994	618,640
Channel catfish	1,052,934	473,107	118,606	48,181	1,715,540
Lake herring	613,908	212,340	531,888	164,162	1,145,796
Walleye	22,409	24,106	6,482,851	9,604,319	6,505,260
Rainbow smelt	3,519,862	1,689,772	20,238,505	4,126,535	23,758,367
Carp	1,500,508	125,181	116,018	39,324	1,616,526
American eel	—	—	214,248	292,811	—
Chinook salmon	429,827	199,184	—	—	—
White bass	445,808	375,322	1,968,420	1,896,770	2,414,228
White perch	1,015,298	373,707	7,018,105	3,167,713	8,033,403

Sources: U.S. Fish & Wildlife Service; Ontario Ministry of Natural Resources.

waters. In the U.S. waters of Lake Huron, channel catfish, chinook salmon and carp are taken in large numbers, whereas popular commercial species in Canadian waters are chubs, yellow perch and walleye. In the North Channel of Lake Huron, lake herring are taken in large numbers, and in Georgian Bay large quantities of chubs, lake trout and carp are harvested. From Lake Erie, U.S. commercial fishermen harvest mainly carp, white perch, yellow perch, white bass and gizzard shad. Some spottail shiners and other minnows are caught by Pennsylvania commercial fishermen and sold as bait. Canadian Lake Erie commercial fishermen harvest mostly smelt, white perch, and walleye. From Lake Ontario waters, yellow perch constitute about half of the U.S. commercial catch (by weight), and brown bullhead, rock bass and other sunfishes are the next most commonly caught species. From the Canadian waters of Lake Ontario come lake whitefish, bullheads, American eel and yellow perch. In Lake Michigan, commercial fishermen harvest mainly lake whitefish, yellow perch, chubs and smelt (in Wisconsin and Michigan waters). In Wisconsin waters of Lake Michigan, alewife are caught commercially and sold for animal food, although much of this activity has been curtailed recently. Throughout the region, the total **landed value** is greatest for lake whitefish, yellow perch, walleye and smelt.

Most commercial fishing in the region is done with trap nets, pound nets or gill nets, although trawls are used for smelt and chub fisheries (and in the past for alewife). In many ways, the life of the commercial fisher is like that of the family farmer. The work is hard, income is uncertain and variable, and being on the lakes is risky and dangerous at times. Fishing is often a family venture, with fishing information, techniques and equipment passed on through generations and with family members taking part in all aspects of the business, including fish preparation and sales. Commercial fishers have detailed understanding of lake bottom conditions such as depth, current and substrate, landmarks and navigation, fish movements and subpopulations, and weather patterns. Often, they have understanding and skill in knot tying and net repair and in boat maintenance and repair. While various technological advancements have aided the commercial fisher in recent years, it is still a time-consuming and difficult occupation; in spite of this, many speak of how fishing and the lakes are "in their blood."

The commercial **fishery** is important to tourism and to communities along the Great Lakes shoreline. This industry supplies such regional favorites as yellow perch, lake whitefish, smelt, and smoked fish. Families and communities throughout the region have developed their own variations on the "fish fry" for smelt and perch, and the Great Lakes fish boil is a regional specialty. Planked whitefish is also a traditional Great Lakes delicacy. Preparing smoked whitefish, suckers, chubs, herring and other fishes is not only a family project, but also offers regional fare for visitors to coastal towns.

Other Fisheries Activities

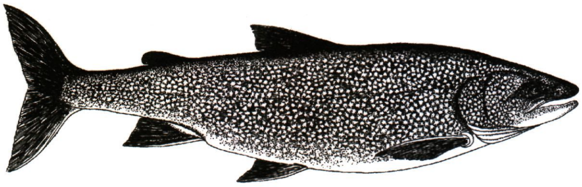
Other fisheries activities today include **aquaculture** and subsistence fishing. Estimates of the economic importance of Great Lakes fisheries to subsistence fishermen are difficult to obtain. However, **aquaculture** — the cultivation of aquatic plants, invertebrates, fishes and amphibians — has grown somewhat in the region. In 1991, nearly 250 fish culture facilities operated in Ontario; these fish **producers** expect some small growth in Ontario's **aquaculture** industry in the near future. From 1989 to 1992, the number of trout **producers** in Michigan, Wisconsin, and New York remained relatively constant, but the value of trout sold climbed from $3 to $4.9 million. Trout were raised for the food market, to **stock** in private recreational waters or for sale to other fish growers and for fee-fishing operations. Fish growers in the region also raise other types of fishes including bass, catfish, sunfish, yellow perch, and the lake whitefish. **Aquaculture** in this region will continue to grow to meet increasing demand for high quality fish products.

"I love the lake, and I love the weather, and I love the challenge it presents each day."

Denny Grinold
Sport Fisherman and Charter Captain
Lansing, MI
from: The Life of the Lakes: The Great Lakes Fishery

"... it's a good living, and I'm proud of our heritage."

John Gauthier
Commercial Fisherman
Rogers City, MI
from: The Life of the Lakes: The Great Lakes Fishery

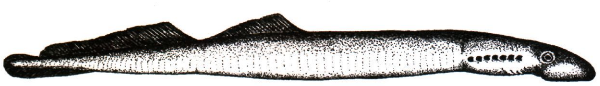


Lake trout
(Salvelinus namaycush)

Description: often about 31 in. and 10 lbs.; scattered light spots on dark body; forked tail

Adult Diet: forage fishes such as chubs (ciscoes), lake herring, sticklebacks, alewife, smelt, sculpins

Habitat/Behavior: mainly **benthic**, but may be found at various depths (**pelagic** and inshore); **spawn** on rocky **reefs** during November and December; a subspecies called siskowet (or "fat trout") is found in deepwater areas of Lake Superior

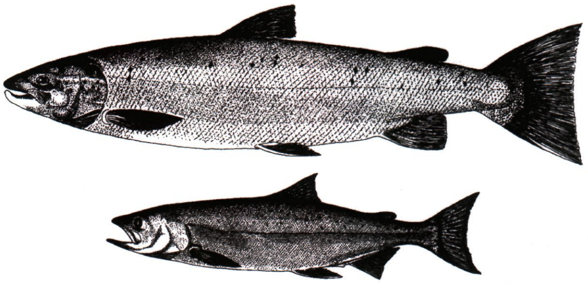


Sea lamprey
(Petromyzon marinus)

Description: grow up to 34 in.; lacks jaws; has circular mouth with rasping teeth; no paired fins

Adult Diet: fluids and tissues of large fish, particularly salmon and trout which have small scales

Habitat/Behavior: **pelagic** and **benthic**; **spawn** in rivers and streams in spring; larval lamprey (called ammocoetes) spend several years buried in **sediments** feeding on small organisms filtered from the water; migrate to open waters of Great Lakes for adult years; not native to Great Lakes — made its way into upper Great Lakes after the Welland Canal (bypassing Niagara Falls) was opened

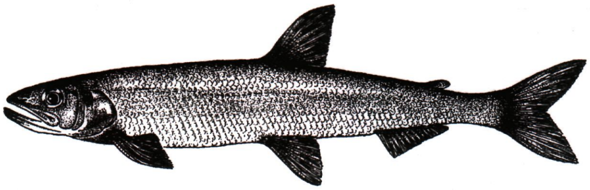


PACIFIC SALMON
Chinook salmon
(Oncorhynchus tshawytsha)
Coho salmon
(O. kisutch)

Description: Chinook salmon - adults about 36 in., 18 lbs.; black mouth and inner gums, anal fin with 15-17 rays, black spots all over tail
Coho salmon - can reach about 27 in., 6.5 lbs.; gray gums, anal fin with 13-15 rays, black spots on back and upper half of tail

Adult Diet: alewife, smelt, other **forage fishes**

Habitat/Behavior: **pelagic** (open water); anadromous (**spawn** in rivers, streams); **spawn** in fall when 2-5 years old; adults die after **spawning**; 6-month-old chinook and 18-month-old coho migrate from rivers to Great Lakes



Rainbow smelt
(Osmerus mordax)

Description: 7-8 in. and under 1/4 –1 lb.; long silvery body, with rainbow-like iridescent color on sides; adipose fin

Adult Diet: planktivore (**plankton**-eating)

Habitat/Behavior: mainly **pelagic**; *anadromous* (**spawn** in streams, rivers); **spawn** in spring

Great Lakes Fisheries:
The Past

Waves of Change

CHANGE — the byword of the Great Lakes fisheries. To understand what the fisheries are today and what they may be in the future, it is important to review their complex and ever-changing past. Since the Great Lakes started taking shape only 15,000 years ago, the Great Lakes fisheries have been changing almost continually. In the last century, and particularly in recent decades, the pace of change has picked up, and some of the changes have been dramatic.

Waves of change have always moved throughout the lakes. Once one lake experienced a set of changes, it was usually only a matter of time until the other lakes experienced similar changes. Social, technological and environmental changes have spread, sometimes together, through the entire basin. Taken together, all of the changes that have occurred make today's Great Lakes fisheries quite different than they were thousands of years ago.

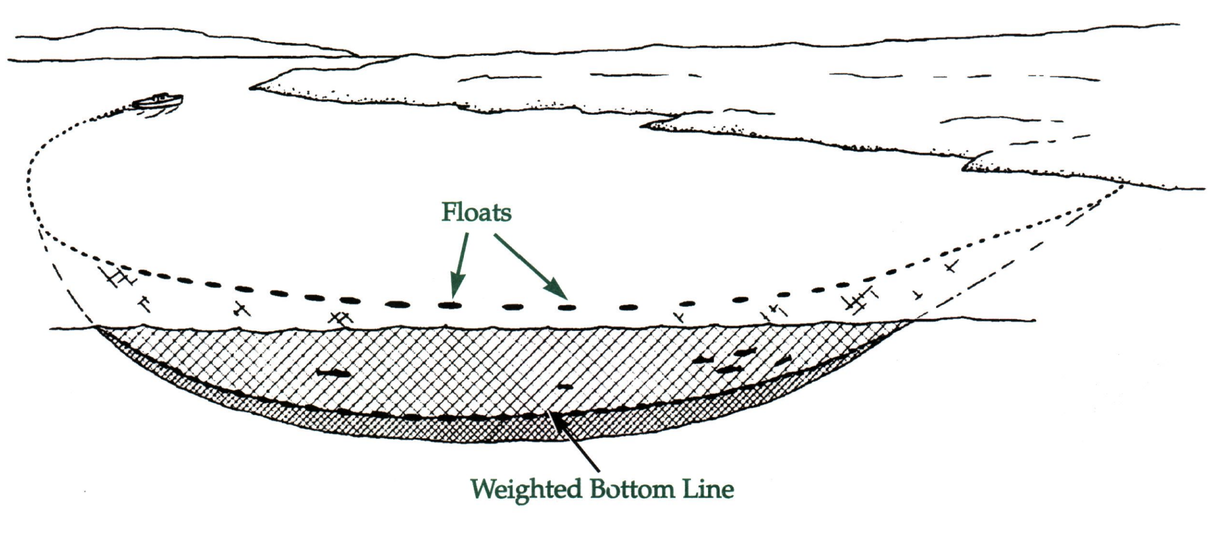
Early Times: Era of Abundance (15,000 years ago to about A.D. 1800)

As the glaciers receded, the Great Lakes shorelines changed greatly. Water levels fluctuated as the land rebounded (lifted up) when the heavy glaciers retreated northward. About 12,000 to 11,000 years ago, people arrived in the region and hunted the extremely large game mammals that existed, such as the mastodon. From 6000-3000 B.C. (Middle Archaic Period), fishing became more important for people living in the Great Lakes region. Archaeologists believe fish hooks were invented during this time because they have found stone tools probably used to make hooks and other outdoor gear at some sites.

By the Late Archaic Period (beginning in 3000 B.C.), Great Lakes peoples were trading with others in more distant regions. These groups developed spearing (for lake sturgeon, northern pike, suckers) and angling (for a variety of fishes from a boat or through the ice). Spears were of copper, bone and antler, and hooks were of copper or bone. Gorges, made of copper or bone, were like hooks, except they were straight and could get caught in fishes' throats. **Weirs**, small dam structures, were sometimes used to help concentrate the fishes. This early gear was used to catch mainly those fishes that were abundant during the spring **spawning** season in inshore, shallow areas or streams.

By about 1000 B.C., the abundance of fishes was a major influence on the cultures of people in the region. Groups in the northern Great Lakes region existed mainly by fishing and hunting and supplemented their diet with plants. The seasonal movements of fishes into the shallow areas of the

Beach Seine Net



northern Great Lakes was a major influence on these peoples' subsistence and settlement patterns. In the southern Great Lakes region, agriculture emerged and corn arrived around 300 B.C., and these peoples only supplemented their diet with fish and game.

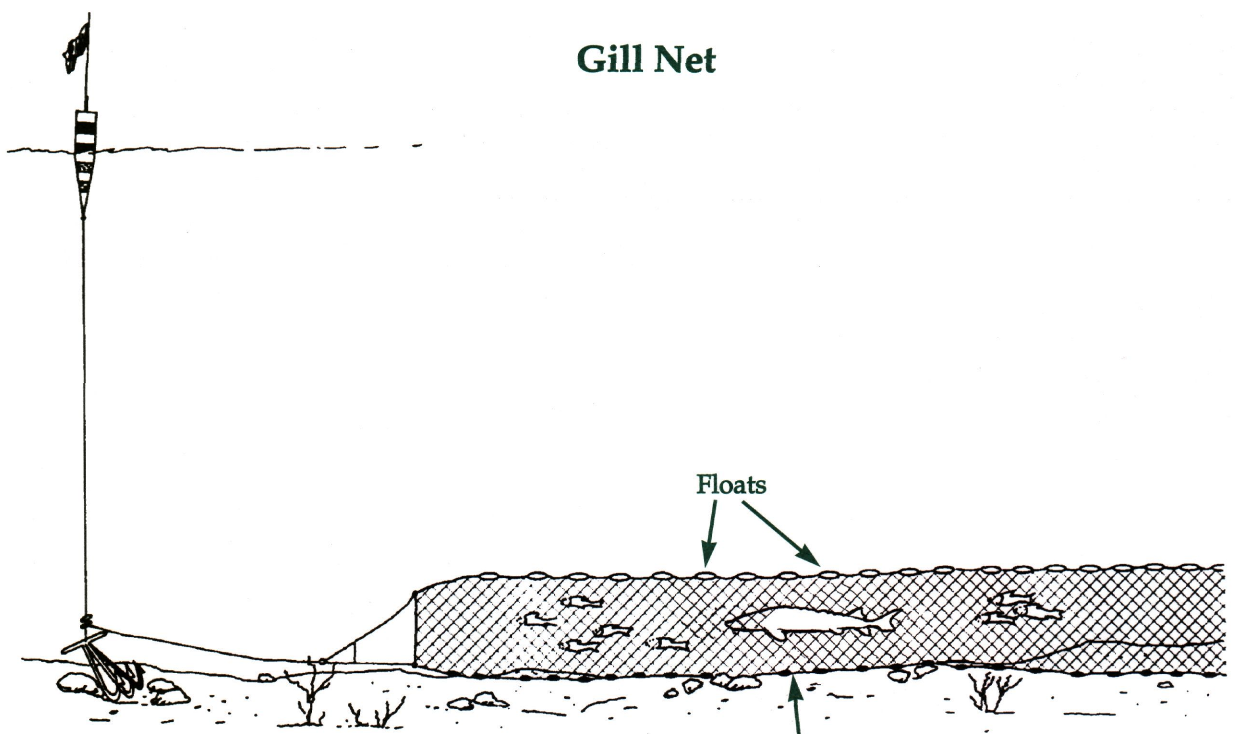
During the Woodland Period, which lasted from 1000 B.C. to the time of the arrival of the Europeans, two technological changes were added to fishing gear of the peoples of the upper Great Lakes. Seine nets made of wild hemp or nettles, with cords of basswood bark or of leather, were edged at the bottom with small notched stones (net sinkers); these seines were used to corral fishes such as northern pike, drum, bass and suckers to the shore. Harpoons with detachable heads attached to a line allowed for more efficient capture of large fish, such as lake sturgeon, than was possible with spears. These technology changes allowed some social changes to occur. These fishing techniques required more group cooperation, so family groups gathered at the Great Lakes shorelines to work together during the fishing seasons.

Around A.D. 800, native peoples first started modifying their nets into gill nets. This allowed the harvest of offshore, fall **spawners** such as lake trout and lake whitefish. Fall fishing meant that a large catch could be preserved by smoking or freezing for use throughout the winter. Spring fishing also continued, using the earlier technologies and the gill net.

When Europeans first began exploring the region, only 60,000-117,000 people lived in the Great Lakes area. (In contrast, about 33 million people now live in the Great Lakes basin.) Fishes native to the Great Lakes were generally abundant relative to the number of people living in the basin. The tribal groups in the region at that time included the Ottawa, Potawatomi, and Ojibwa (Chippewa) in what is now Michigan, the Iroquois and Huron in the east, and the Menominee, Winnebago, Illinois and Miami to the west of Lake Michigan. By this time, fishing had grown to be vitally important in the lives of the peoples in the upper Great Lakes region. Although not a focal point of their lives, the peoples of the lower Great Lakes and the St. Lawrence River also relied on fisheries resources (including American eels) for part of their diets.

Europeans began arriving in the 1600s. Due to better fur trapping and hostilities among native

Gill Net



peoples in the lower Great Lakes region, French explorers and early missionaries began arriving in the upper Great Lakes in the 1660s, about 25 years earlier than they arrived in the Lake Erie region. Europeans learned about the long-established North American fishing techniques and also wrote about the unique dip-net fishing done from canoes in the St. Marys River between Lakes Superior and Huron. Europeans also saw the extent of the Native American **fishery**, which occurred not only in open water, but through the ice in winter. No evidence exists that fishing declined in importance in the life-ways of the native peoples during this time. In fact, many of the fishing techniques that had been developed survived into the eras yet to come.

With the arrival of Europeans, fur trading became a major historical influence on the Great Lakes region. This area mostly was controlled by the French, although the British were also trading with the native peoples. The lakes became the key routes for travel, trade, warfare, communication and diplomacy. Two worlds met, and Europeans and native peoples exchanged more than just furs. As voyageur-traders ventured into the new frontier, they relied upon the occasional meal (sometimes of fish) and shelter provided by the native peoples. Nets and other native fishing gear were among the items of trade. Likewise, native peoples received various European trade goods for their furs and other supplies; among those trade goods were tools which made hunting and fishing easier.

In 1763, the Treaty of Paris was signed (to conclude the French and Indian War which ended in 1760). The Great Lakes region was transferred from French to British control, though many French settlers remained in the region. In 1783, after the U.S. Revolutionary War, another treaty established what is now the U.S.-Canadian border. Both the British and the Americans were still active in the fur trade around the region, particularly in the western end of the upper Great Lakes. The frontier was in transition for several decades; both the U.S. and the British encouraged settlers to move to the Great Lakes region. After the U.S. Revolutionary War, treaties with Native Americans led to land "cessions" in the U.S. and to land "surrender" in Canada; cession and surrender are both terms for the process by which the governments acquired native peoples' lands for sale to settlers. Populations of settlers increased greatly.

In the late 1700s, the demand for fur in Europe helped to strengthen the fur trade. In the 1780s to 1790s, the Northwest Fur Company dominated the west end of Lake Superior, particularly the Chequamegon (Wisconsin) area. The company fished the north side of Isle Royale to feed people at its trading stations in western Lake Superior. Also in the 1790s, a hook and line commercial **fishery** developed on Lake Erie (near Presque Isle, Pennsylvania). Little is known about these earliest commercial fishing enterprises.

Before the 1800s, Great Lakes fish populations were thought to be unlimited and inexhaustible. But all of the changes brought by the new settlers set the stage for dramatic and rapid changes in fisheries in the next era.

Changing Times: Era of Exploitation and Degradation (About 1800 to 1870s)

Social Changes

Around 1800, increasing numbers of settlers began coming to the Great Lakes region and the northeast U.S. and Canada. This first wave of immigration continued until about the 1840s. The tremendous population growth in the region would have serious implications for environmental quality and fish populations.

The first Lake Huron **fishery** was established around Fort Michilimackinac by 1800; this **fishery** was an important element of the continuing fur trade. In 1808, John Jacob Astor, along with the former Northwest Fur Company, incorporated the famous American Fur Company. After the War of 1812, the British agreed to withdraw to Canadian territory, and the upper Great Lakes was fully open, at last, to American fur traders. After the war, some of the first widespread commercial fisheries in the Great Lakes were established on Lake Erie near the Maumee River and on the Detroit River. By the 1820s and 1830s, commercial fishing was well-established on the Canadian side of the lakes. These commercial fisheries served eastern cities growing larger with immigrants. In 1826, the first shipments of salted whitefish and lake trout left Detroit for eastern markets.

After 1834, Mackinac Island was reduced in status as a fur trading station, and the American Fur Company made its headquarters in the Chequamegon area of western Lake Superior. The company built two schooners to carry furs to be sold in Sault Ste. Marie. The boatmen, freed from rowing the fur-carrying craft, were employed as fishermen, because company officials feared they might join rival fur-trading companies. Fishing stations were established throughout the western basin of Lake Superior at Grand Marais and Grand Portage (Minnesota), Isle Royale, the Montreal River (Michigan), and at L'Anse (Michigan) in the Keweenaw Bay. These men spent winters in

LaPointe, Wisconsin and returned to fishing grounds in spring. They fished with handmade twine nets from wooden boats propelled by oars or sail. Others were employed at the fishing stations to clean, salt and pack the fish and to make the barrels in which fish were shipped to growing markets in the Ohio River Valley. The Hudson's Bay Company likewise employed men at fishing stations. Thus began large-scale, organized commercial fishing in the Great Lakes.

After the financial Panic of 1837, a depression put an end to the fishing business of the American Fur Company. By this time, the demand for furs in Europe had dropped dramatically. The company split up, and fishing continued on a smaller scale for a while.

Throughout this period, treaties were established between the native peoples and the new governments in the region. Another effort at land cession was made by the U.S. in the early 1800s to help the government through economic hard times. The Treaty of 1836, or the Ottawa-Chippewa Treaty, ceded to the U.S. one of the largest tracts of land in the Great Lakes region in the area that was to become Michigan. Although the Native Americans lost their land base, fishing and hunting rights in the region were retained in the treaty process. By the end of this era, most of the Native American land in the region had been ceded and reservations were being established.

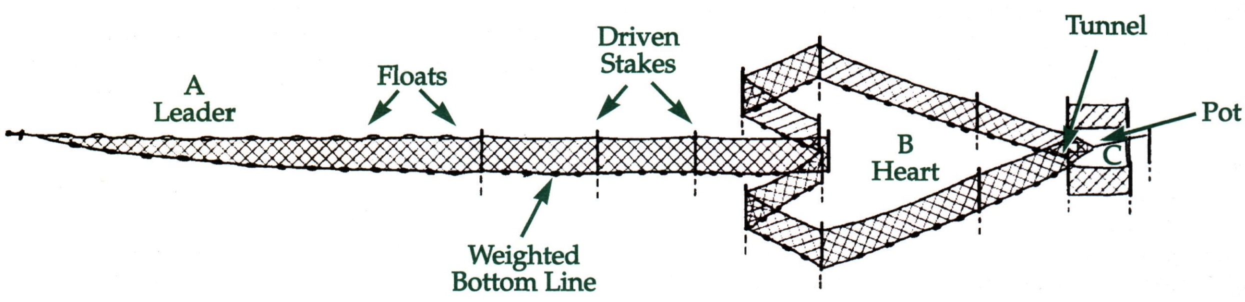
In 1844, iron ore was discovered in upper Michigan. Modifications in waterways allowed even more immigrants to enter the region.

Technological Changes

Boats and navigation in the Great Lakes began to change early in the 1800s. Steamboats first arrived in Lake Erie in 1818. Soon steam-powered boats were found throughout the region. Navigational improvements followed. In 1825, the Erie Canal opened, more directly connecting lakes Ontario and Erie with the Atlantic Ocean via the Hudson River and port of New York. In 1829, the Welland Ship Canal was constructed between lakes Ontario and Erie to provide a shipping channel around Niagara Falls. (This canal was improved and enlarged several times from 1833 to 1919.) In 1832, the Rideau Canal system was completed connecting Kingston, Ontario with Montreal. In 1855, the St. Marys Falls Ship Canal (popularly known as the Soo Locks) connecting Lake Superior and Lake Huron was enlarged to accommodate large lake-going vessels. These new watery connections would not only benefit immigrants and commercial vessels, but would also play major roles in the story of Great Lakes fisheries in years to come!

Early in this era, fishing techniques were simple; before 1850, techniques on Lake Erie included seines (for sauger, walleye and smallmouth bass), brush **weirs**, spears, and trotlines (lines with multiple fish hooks). Seines were also used in the Detroit River. The earliest commercial fisheries also used dipnets. Almost all of the effort was concentrated in the shallows and focused on the major **spawning** runs of Atlantic salmon (in Lake Ontario), **coregonines** (lake whitefish and related fishes including lake herring, ciscoes and bloaters), and **percids** (members of the perch family including yellow perch and walleye). Wooden boats were used to travel somewhat farther out in waterways. By the 1840s and 1850s, pound nets were used throughout the Great Lakes and gill net use was increasing. In the 1840s, handmade cotton twine nets were replaced with cheaper machine-made nets. In the late 1850s, linen nets were first used. These changes in nets allowed fishing in deeper waters and led to larger catches. By the 1870s, seines were almost

Pound Net



completely replaced by gill nets and pound nets. By the mid-1870s, steam fishing tugs were introduced in the Great Lakes. These allowed fishermen to travel even farther from shore and to work even in foul weather. (Fishing tugs were so-called because fishermen sometimes used them for towing in the off-season.)

Transport of fish changed much during this era. In 1851, the Erie Railroad became the first line connected to the Great Lakes. In 1855, the Northern Railway connected Collingwood on the southwest portion of Georgian Bay (on Lake Huron) with a large market in the developing Toronto area. The railroads allowed faster shipping of iced and frozen fish to eastern markets. Fishermen could hold onto frozen fish until markets and prices were favorable for selling.

During the early 1800s, the roots of **fisheries science** were established. In 1848, Professor Louis Agassiz and 15 others started on one of the earliest scientific expeditions on the Great Lakes. They left from Sault Ste. Marie in one large Mackinaw boat and two canoes to study the north shore of Lake Superior. These scientists compiled some of the earliest technical descriptions of Great Lakes fishes. Other scientists were beginning to study lake level fluctuations and water chemistry.

Environmental Changes

Two major types of environmental changes began to influence the Great Lakes fisheries in the 1800s: **habitat** degradation due to increasing human populations and activities; and the arrival of **exotic** species in the basin. Change would occur in waves throughout the region. The Lake Ontario basin was the first settled by Europeans and altered by canals and dams. The changes that occurred in Lake Ontario during the 1800s would play out in the other lakes from 1900 to the present.

The most profound early environmental changes in the lakes occurred during the logging era. Logging activity first peaked in New York in the mid-1800s, then peaked farther west in Michigan in the 1860s to 1870s. These logging and settlement activities caused the first type of environmental change: loss of fish **habitats** due to extreme modifications of Great Lakes drainage systems. By the mid-1800s, water-powered mills of all sorts (including sawmills) were common on the streams in the region. This meant many Great Lakes tributaries were dammed, preventing fish from passing upstream to **spawn** and concentrating them in downstream areas where they were more susceptible to overfishing. Heavy logging increased soil erosion into streams, causing **turbidity** (muddy, cloudy water) covering **spawning** areas and warming the waters, further degrading fishes' **spawning habitats**. **Wetlands**—**spawning** areas for other fish species—were drained and modified, too. Logging wastes, such as sawdust, were deposited everywhere in coastal areas and in streams. Slab wood and even whole logs are still found on river bottoms near old mill sites. Human wastes from settlements and cities also entered the waterways. Thus, the effect of pollution on Great Lakes fisheries began rather early and is not merely a modern phenomenon.

The second type of environmental change that began in the 1800s was the arrival of **exotic** (nonnative) marine species in the Great Lakes. By the 1860s, the alewife, a coolwater fish from the Atlantic Ocean, had travelled through the Erie Canal and was established in Lake Ontario and Lake Erie. The effects of the alewife would be felt throughout the Great Lakes **food web** within a few decades.

Changes in the Great Lakes Fisheries

Major changes in Great Lakes fish populations began in the early 1800s in Lake Ontario. The earliest intensive **fishery** in the region was for Atlantic salmon in Lake Ontario; this fish was the most valued and heavily exploited fish of the times. Intensive fishing for this species had started in the late 1700s and increased through the mid-1800s. Mill dams concentrated these fish and made them more vulnerable to harvest. These and other changes in the **tributary** streams decreased the amount of **spawning habitat** accessible to salmon. The main reasons for the loss of salmon were probably **habitat** degradation and intensive fishing. By the 1830s and 1840s, this loss caused the first major fisheries-related alarm on the Great Lakes. Restrictions on harvest and attempts at **stocking** in the 1860s led to a temporary, small recovery for Atlantic salmon, but the turn of the century brought the last record of native salmon in Lake Ontario.

Intensive fishing also occurred for other Great Lakes fishes during the early 1800s. Lake whitefish was the most fished for species at this time in the four upper Great Lakes. Lake trout were second in all lakes; harvest of lake trout became even more important when lake whitefish numbers were low and as Atlantic salmon decreased in Lake Ontario. Other important fishes included the lake herring in Lake Erie, Saginaw Bay and Green Bay, the lake sturgeon throughout all the lakes, and deepwater ciscoes in Lake Huron, Lake Michigan and Lake Superior. By 1860, lake whitefish in Green Bay (Lake Michigan) had declined by 50%. By the 1860s, fishing laws in the region began to restrict fishing by establishing catch limits and closed seasons. As early as 1861, Ohio declared its first closed season for some fishes. Significant changes had already begun for Great Lakes fisheries.

Early Efforts: Era of Regulations and Stocking (1870s to early 1900s)

Social Changes

After the Civil War, the Great Lakes region experienced more settlement. Railroad construction expanded in the region. Population growth increased, and large cities such as Chicago dotted the shorelines. Immigrants from Scandanavia, Ireland and other distant places arrived in the northern portions of the Great Lakes region and brought their family traditions of fishing with them. More Native American reservations were established in the region as lands were ceded to the U.S. government and surrendered to the British government in Canada. Some sportfishing began; in 1885, daily sportfishing excursions were offered on Lake Erie. In 1914, another change occurred when Great Britain entered World War I and fishing in Canada was declared an essential service.

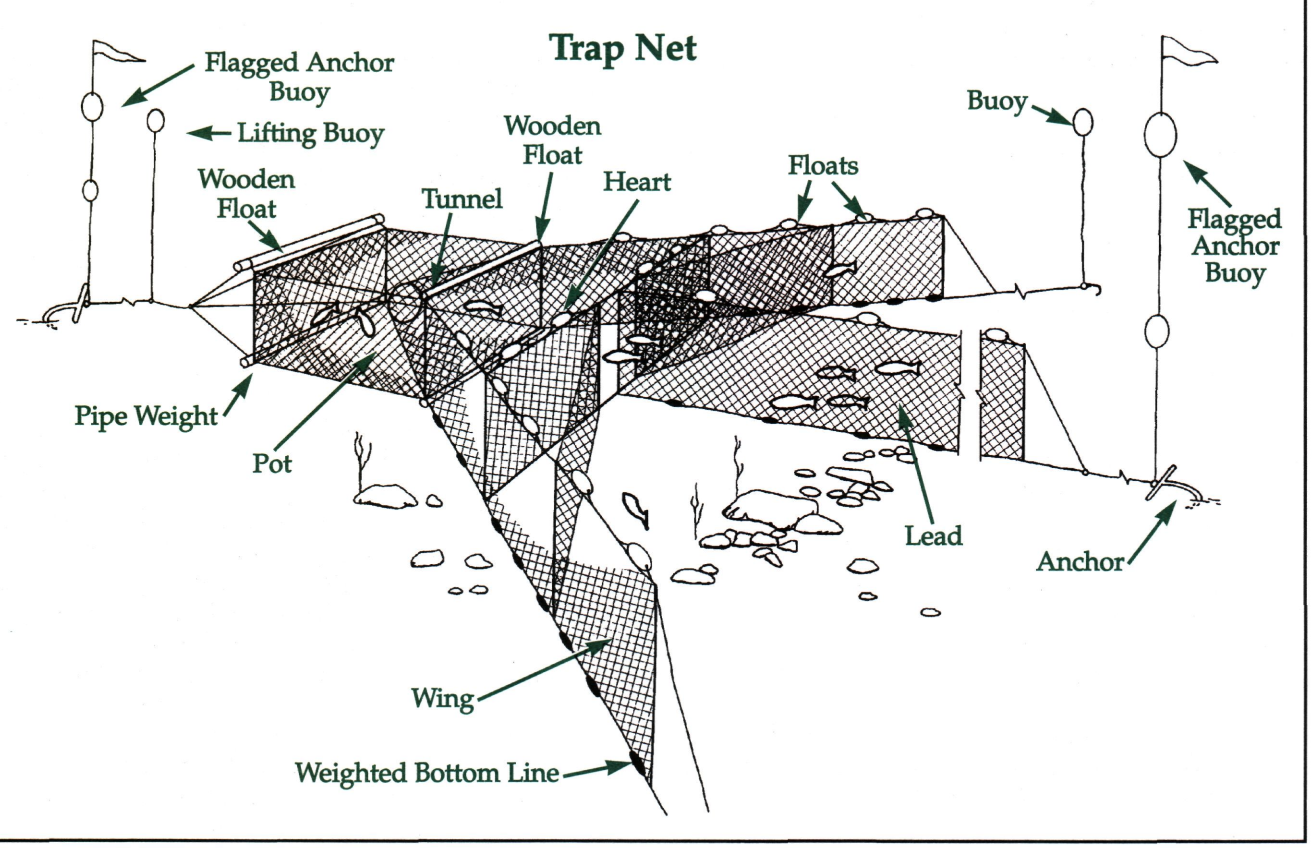
Technological Changes

Boats and navigation changed during the 1870s to the early 1900s. In 1870, the first Canadian steam fishing tug above the Niagara River began to work in Lake Huron. In the 1870s, steam engines were improved; work proceeded on internal combustion engines in 1886. Gasoline engines began catching on around the turn of the century, and in 1909 Ole Evinrude of Minnesota developed the first commercially successful outboard motor. In 1910, diesel engines with fuel injection were available, and in 1920, the first diesel boats on the Great Lakes were built. Throughout this era, however, the steam tug remained most numerous on the Great Lakes, its use peaking at about the end of World War I. In 1875, steel was first used in shipbuilding, although it would take a while before steel would replace wooden-hulled fishing vessels in the Great Lakes.

As engine technologies changed, so, too, did the technologies used to haul larger and larger nets from the water. In 1895, the Connable steam net lifter was patented, and its use around the turn of the century allowed more gill nets to be set and hauled. Gasoline net lifters were also developed.

Navigational improvements of this era included construction of the Chicago Sanitary and Ship Canal in 1900. This waterway connected the Great Lakes **watershed** with the Mississippi River **watershed**.

Fishing techniques also changed around the turn of the century. During the 1890s, a new type of net, the trap net, was used in the Great Lakes (in Saginaw



Bay and the St. Marys River). This net was a more efficient, easier-to-move variation on the pound net. Although this net was popular in the U.S. waters, it was not legal in Canadian waters until 1950 (although it was used earlier in Georgian Bay).

Just as pound net fishermen and gill net fishermen had disagreed over which nets should be used, so, too, were fishermen worried that the efficient trap nets would result in overfishing. While this controversy was beginning to simmer, even more efficient variations on the gill net were appearing. About 1900, "canning" of gill nets began. Canning, or floating gill nets in mid-water rather than the old method of anchoring nets to the bottom, allowed nets to be moved to various water depths with changes in seasons and temperature. Catches increased. In 1905, U.S. fishermen on Lake Erie invented a variation of the gill net called the bull net. Until this time, gill nets used to catch herring were only about 5 feet tall; bull nets, however, were up to 22 feet tall! Around 1900, less expensive cotton nets were introduced in the region. In summary, during the era, nets became cheaper, larger, easier to move and to haul out of the water, and more efficient. The **mesh sizes** of fishing nets were shrinking, taking younger and younger fish, and all of the larger, older size classes were "fished out" or "fished up."

Fisheries management began in full force during this era. In 1870, the American Fish Culturalists' Association, a professional organization, was formed; in 1884, this group became the American Fisheries Society. In 1871, J. S. Milner began a survey for the U.S. Commission of Fish and Fisheries. He toured the shores and islands of Lake Michigan, collecting information on the life histories of fishes important to the commercial fishing industry. In 1872, he extended his survey to lakes Superior, Huron, St. Clair and Erie. His reports discussed what were probably the first scientific efforts to study lake whitefish migrations by tagging fish. Unfortunately, much of his fish collection, stored at the Chicago Academy of Science, was lost in the Great Chicago Fire. Milner's studies gave evidence of serious declines in Great Lakes fisheries, and he recommended protective legislation and hatchery propagation of fish.

Hatchery rearing of fish was a major focus of **fisheries management** in the Great Lakes during this era. While some hatchery work had been tried in North America in the 1850s and 1860s, these efforts did not unfold into large-scale efforts until later. In the late 1860s, Ontario's Samuel Wilmot became involved in trying to restore the Atlantic salmon by artificial propagation. In 1876, he was made superintendent of fish culture, and the hatchery effort expanded in Canada. In 1874 in Michigan, the Board of Fish Commissioners (started just one year earlier) established a fish hatchery on the Detroit River. During the 1880s and 1890s, the U.S. government began operating hatcheries in Michigan at Northville and Alpena, in Sandusky and Put-in-Bay, Ohio, in Duluth, Minnesota, and in Cape Vincent, New York. Several other states also established hatcheries during this period. Little is known about the real success of these early programs. By the turn of the century, people were already disgruntled that the **stocking** efforts were not increasing fish abundance noticeably.

In this era, fisheries research was just beginning. The major philosophy at the time was that fish were declining because they were having trouble reproducing; thus, if more hatchery-reared fish were added (i.e. if the reproductive process and the early survival of fishes were helped along), more fish would ultimately be available to harvest. Concern about fish population declines, however, was prompting some researchers to look at the underlying factors (such as water quality, food bases, etc.) which affect **fish production**. Researchers in both the U.S. and Canada were just getting started. At the same time, concern about the poor water quality in the Great Lakes prompted the first successful international agreements. In 1909, the Boundary Waters Treaty between the U.S. and Canada established the International Joint Commission to study water pollution in the Great Lakes. Extensive studies began and continued into the following eras.

Environmental Changes

The two themes of environmental change — modification of drainage systems and invasion by **exotic** species — continued between 1870 to the early 1900s. For example, human population growth, forest cutting, land clearing, development, wetland drainage, harbor dredging, pollution from lumbering activities, and sewer outflows continued throughout the Lake Michigan basin after 1850 and until the early 1900s.

Many serious fires raged throughout the region in the decades immediately following the peak of logging. In 1871, a fire burned the northwestern edge of Lake Michigan, from just north of the city of Green Bay, Wisconsin to just south of Escanaba, Michigan. Other fires of this era burned along the coasts of Lake Huron. With fires came soil erosion and increased **turbidity** and pollution in the water. Areas such as Green Bay in Lake Michigan began to experience the severe problems with environmental quality that Lakes Erie and Ontario had begun to experience earlier.

In this era, **eutrophication** was beginning to take its toll on water quality and the fisheries.

Eutrophication is the process through which waters increase in nutrients. While **eutrophication** occurs naturally as lakes age over geological time, cultural **eutrophication** is a process of rapid changes due to human influences in the **watershed**. This process was already affecting the more southerly, shallow Great Lakes during the late 1800s and at the turn of the century. These early effects were caused by the logging activities in the Great Lakes watershed and by the rapid settlement of portions of the basin, particularly the lower lakes (Lake St. Clair, Lake Erie and Lake Ontario). Other locations feeling these early effects were the shallow bays such as Green Bay in Lake Michigan and Saginaw Bay in Lake Huron. Fish species adapted to the **oligotrophic** (cold, deep, low nutrient) conditions of the lakes also experienced declines, one of the effects of cultural **eutrophication**.

The arrival and impacts of **exotic** species in the Great Lakes (particularly the lakes upstream from Lake Ontario) were noted during the late 1800s. In the 1880s, sea lamprey problems were first reported in Lake Ontario. Sea lampreys were first noted in Lake Ontario in the 1830s; they had either arrived through the Erie Canal or they had been native to the Lake Ontario basin. By 1921, the sea lamprey had made its way into Lake Erie. The smelt had been present in Lake Ontario during the 1800s, but it was introduced intentionally into Crystal Lake at the edge of Lake Michigan in 1912. During the next two decades, it would make its way into all of the other lakes. Another marine invader, the alewife, first appeared in Lake Ontario in the late 1800s. Some species were intentionally introduced into the Great Lakes during the hey-days of hatchery propagation; these included steelhead, chinook salmon, brown trout, and carp. (See Pocket Insert "Fishes of the Great Lakes" for those species which were introduced into the Great Lakes.)

Changes in the Great Lakes Fisheries

After the loss of the Atlantic salmon in Lake Ontario, the next major decline in the Great Lakes was the lake sturgeon. At first, this species was not commercially important and was destroyed because it damaged fishing nets. Later, though, many uses for this fish were found and many products were derived from it; caviar (eggs) from sturgeon became popular; oil from the fish was used for a variety of purposes; its air bladder was used to manufacture isinglass (a gelatin used as a clarifying agent and in jellies and glue); and carcasses were used as fertilizer. Between 1890 and 1910, this fish declined in all of the lakes. In 1879, the sturgeon catch for Lake Michigan was 3.8 million pounds. (1.7 million kilograms), but some decline had probably already occurred. By 1885 in Lake Michigan, the catch dropped to 1.4 million pounds (0.6 million kilograms). Catches in 1897 were only 138,000 pounds (62,600 kilograms). By 1911, the catch was only 14,000 pounds (6,350 kilograms), and after that the fish was nearly nonexistent in commercial catches. Lake Erie's sturgeon catch was about 5 million pounds (2.3 million kilograms) in 1885, but dropped to only 100,000 pounds (45,360 kilograms) in 1916 and never recovered. Lake Huron sturgeon experienced a similar decline, but reached low levels later in the 1930s. Lake Ontario's sturgeon catch dropped from 581,000 pounds (263,500 kilograms) in the 1890s to only 10,000 pounds (4,500 kilograms) by the 1920s. Much of this loss was due first to overfishing and second to the loss of **spawning habitats** in inshore areas, **wetlands** and rivers. The biological characteristics of the sturgeon made it extremely difficult for the fish to recover; it is late-maturing, slow growing, and relatively easy to capture. (It is now found in certain local areas of the Great Lakes such as Lake Huron's North Channel, the Menominee River and the St. Clair River.)

The next major loss of Great Lakes fisheries was the decline of river-run lake trout, lake whitefish and lake herring. These were subgroups which **spawned** in river **habitats**. The largest runs were in the rivers emptying into lakes Huron, Michigan, St. Clair and Erie. These fishes were lost by the early 1900s, mainly because of modification of the river drainages caused by logging and sawmilling activities.

As a group, **coregonines** (members of the whitefish family including lake whitefish, lake herring, and ciscoes—commonly called "chubs") were fished heavily in this era. One member of this group, the lake whitefish, began to experience population fluctuations. By 1879, great fluctuations occurred in Lake Ontario lake whitefish catches, (as well as fluctuations in ciscoes and lake herring). By the 1920s, however, lake whitefish had recovered in Lake Ontario. By 1880, Lake Erie pound netters complained of decreased lake whitefish harvests. In the western basin of Lake Erie, smaller lake whitefish were being harvested as smaller and smaller net **mesh sizes** were used to catch lake herring. From 1885 to 1911, Lake Superior saw declines in lake whitefish. This period began the "glory years" for lake trout there. In Lake Michigan, lake whitefish were fairly stable with a harvest of 1-2 million pounds (0.45-0.91 million kilograms) per year from 1894 to 1927, and in the 1920s, lake whitefish catches increased.

Other **coregonines,** the lake herring and ciscoes, were sensitive to fishing pressures and other factors during this time. Throughout the lakes, it was difficult to trace the actual fluctuations of individual species of **coregonines,** because catch statistics for lake herring and the various cisco species were often combined. The year 1910 saw a major decline in lake herring in Lake Michigan. (In Lake Michigan, most of the lake herring and ciscoes were taken from Green Bay.) Before this time, catches of up to 20 million pounds. (9.1 million kilograms) were reported, though numbers of these fishes varied widely. The first species of ciscoes to decline were the larger species, such as the blackfin cisco. As larger ciscoes were fished out, fishermen would switch to smaller and smaller net **mesh sizes** to take the other smaller species. Fishermen would also move to take advantage of **stocks** (groups of fish which **spawn** in a particular part of the lake or at a certain time), sometimes following them during their seasonal migrations. As the larger species of ciscoes declined, the catches of smaller species such as the bloater then increased and remained high. The Great Lakes fisheries were beginning to change dramatically. The number of unique forms of ciscoes was reduced; only a few species of Great Lakes **coregonines** remain today.

The lake trout were amazingly resistant to intensive fishing. From the late 1800s to the early 1900s, this fish supported the most stable Great Lakes **fishery**. The lake trout is a large **predator** which occupies a variety of areas in the Great Lakes, from shore to shore and from top to bottom. Because it fed on the many different species of **forage fishes** present (including lake herring, ciscoes and sculpins) and because, in total, the forage base remained stable throughout much of this era, the lake trout were able to maintain their numbers in the upper Great Lakes.

In the lower Great Lakes, however, lake trout populations began to experience the combined effects of high fishing pressure and **eutrophication**. In Lake Erie, lake trout populations began to decline earlier than in the other lakes. From the beginning, they had been relatively rare in the shallower western and central basins of Erie. Since Lake Erie is at the southern end of the range of the coldwater lake trout, this fish was never abundant. By the end of the 1800s, numbers of this fish had declined, and it was seldom caught after the 1930s.

The lake trout story in Lake Ontario was more complex. Trout there experienced the combined effects of overfishing, cultural **eutrophication** and the impacts of the **exotic** invaders to the lakes. After the loss of the Atlantic salmon, in the 1870s, the alewife increased in Lake Ontario. Alewife may have competed with and forced the decline of other **plankton**-eating forage fishes such as the **coregonines** and yellow perch. In the 1880s, sea lamprey increased in the lake, in part due to the fact that the streams warmed slightly by environmental changes were better suited now for sea lamprey reproduction. The sea lamprey were **parasites** on lake trout and other fishes, and the populations of these fishes began to decline in Lake Ontario.

This era had brought tremendous changes to the life of the Great Lakes. Early in this period, the heydays of commercial fishing were seen in many of the lakes. In 1871, over 32.2 million pounds (14.6 million kilograms) of Great Lakes fish were handled at major fish markets, and more were probably consumed locally. Lake Michigan alone, in 1871, had a commercial industry employing over 2,000 people and 600 vessels. By 1889, more than 10,000 people fished the lakes. In 1899, Lake Ontario experienced a peak in its catch. Around 1900, Lake Erie's catch surpassed or equalled the production of all other lakes combined. But the combined effects of social, technological, and environmental changes were beginning to take their toll on fishes. Overfishing (with improved technologies) had seriously affected populations of Atlantic salmon and lake whitefish. New invaders had already made their presence known in the lower lakes and would quickly change the Great Lakes fisheries. By the end of this era, agencies responded to the decline of some fishes by establishing fishing regulations. Fisheries laws developed at this time included gear restrictions, closed seasons and catch limits. For example, by the late 1800s, laws regulated the **mesh size** of gill nets used in the Great Lakes. In 1906-1907, Ohio and Michigan began to license their commercial fishermen. Fisheries law enforcement started in the region, but (like today) there were few officers compared to the vastness of the lakes they were responsible for covering. State and international differences in fishing laws also made enforcement difficult. Changes in the fisheries in this era set the stage for the next era.

Era of New Invaders, New Challenges (1920s to 1950s)

Social Changes

During the 1920s and even into the 1930s, a new way of looking at the Great Lakes took greater form. The tourism business boomed. Visitors flocked to shoreline resorts, even to remote areas of the lakes such as Isle Royale, and the wealthy owned their own shoreline retreats. Visitors of all types dined on Great Lakes fishes. Charter fishing became more common during the 1920s when commercial fishermen took recreational anglers fishing for lake trout.

Meanwhile, the tribal **fishery** continued for subsistence and commercial purposes. In 1924, U.S. citizenship was granted to Native Americans. In 1930, a court case in Michigan declared that Native Americans had no special fishing or hunting rights under state regulations. At this point, Native Americans did not challenge this court decision, and they had to buy state commercial fishing licenses.

In 1929, the U.S. stock market crashed, with drastic effects. Many fish wholesalers went out of business. In 1939, Canada entered WWII, and by 1942 the U.S. was at war. Fishing was again declared an essential service, and fishermen were exempt from the draft. By 1945, the war was over, but the world had changed. Global markets were opening, and sportfishing began to rise again.

Technological Changes

During the 1920s and 1930s, the fishing fleet in the Great Lakes began converting to diesel engines. These were less bulky and used less fuel and labor to operate. The older steam fishing tugs had required a crew consisting of a captain, an engineer to keep the boat going, and five fishermen. Diesel boats, however, did not need an engineer and needed only half as many laborers. Also at this time, the first steel-hulled Great Lakes fishing boats began to replace wooden hulled boats.

In the 1920s, the bull net was still in use; peak bull net use and increasing gill net use in Canadian waters of Lake Erie occurred in the mid-1920s. In the 1920s, a "new-and-improved" version of the trap net appeared. Called a "deep trap net," it was set in greater depths and on a variety of bottom types. It could be handled more easily than previous pound nets and was used to catch lake whitefish in their deep summer **habitats**. It was introduced onto Lake Huron in 1928; over the next two years, fishermen scrambled to convert to the new gear. Catches of lake whitefish doubled, then lake whitefish began disappearing from the northern grounds in Lake Huron. Gill and pound netters protested the new gear. Governments began investigating this issue in 1931. In 1934, the conflict among the various fishermen had escalated and southern fishermen drove out the encroaching northern deep trap netters trying to fish their southern waters. This net was banned in U.S. waters by the mid-1930s (it had never been used in Canada); eventually, its use was governed by size and depth restrictions. This story is one that had already occurred on the lakes and would repeat itself: the story of conflict among fisheries user groups and of the crusade by users to protect the resource upon which they all depended.

Probably the most dramatic change in net technology began when nylon was invented in 1935. Nylon was lighter, did not absorb water, and decayed more slowly than the old cotton and linen net materials. Nylon nets could be left in the water longer, were easier to handle, and were nearly invisible to the fish. By the 1950s, nearly all of the gill nets in the Great Lakes were replaced with nylon, and within 10 years so were the pound and trap nets. In addition, at about the time of WWII, the old-style wooden floats, or "corks," which fishermen had carved from cedar, were replaced with plastic or aluminum floats which allowed fishing in deeper water.

Other semi-modern advances were made in these few decades. In the 1930s, refrigerated trucks transported fish to markets. In 1935, radar was invented, but would make its way into the lakes gradually. In the 1940s, fishermen began to use depth finders (sonar) and radios.

Fisheries science made important advances, too. The collapse of the lake herring **fishery** in Lake Erie by 1925 prompted large-scale studies on Great Lakes **ecology**. One study, sponsored by Ohio, examined the effects of pollution in Lake Erie. A 1927 study by the U.S. Bureau of Commercial Fisheries was the beginning of federal fisheries research on the Great Lakes. This study examined the **limnology** (the chemistry, **plankton** and **benthos**) of Lake Erie. A third study on Lake Michigan was conducted by the U.S. government, the states of Michigan and Wisconsin and four net manufacturers. This study examined gill net size and effects on harvest of chubs while avoiding unintentional catches of small lake trout.

A better understanding of the factors influencing **fish production** led fisheries managers to use a philosophy of **Maximum Sustainable Yield (MSY)** in the 1940s. The basics of this philosophy were as follows: if the requirements of fish and the productive capacity of the environment are determined, managers can use this knowledge to produce maximum pounds of fish on a sustained basis. MSY, then, is the greatest number of fish that can be harvested from a **fishery** for a period of time with a given level of fishing effort without causing declines in fish populations.

Environmental Changes

Cultural **eutrophication** was one major environmental change occurring during this era. Trends of decline in water quality continued and spread to the upper Great Lakes. The effects of these changes were compounded by the second major type of environmental change which would happen during this time: the increasing invasion of **exotic** marine species such as the alewife, the sea lamprey, and the smelt — the newest characters in the drama of the life of the lakes.

The alewife and sea lamprey had made their way from Lake Ontario into the other lakes through the Welland Canal and/or Erie Canal. Neither the

Year of First Record for Exotic Species in the Great Lakes

LAKE	SEA LAMPREY	ALEWIFE	SMELT
Ontario	1830s	1873	1929
Erie	1921	1931	1932
Huron	1932	1933	1925
Michigan	1936	1949	1923
Superior	1946	1954	1930

Source: Hartman 1988; Mills et al, 1993.

alewife nor the sea lamprey became very well established in Lake Erie, probably due to poor water quality in its tributaries and because this is the shallowest and warmest of the lakes (these species prefer deep, cold water during part of their life cycles). The sea lamprey moved into the upper lakes slightly ahead of the alewife; both these species first moved into lakes Huron and Michigan, then into Lake Superior.

Changes in the Great Lakes Fisheries

The declines of the previous era continued into the 1920s and beyond. Among the most dramatic declines ever experienced in the Great Lakes was the collapse of the lake herring and cisco fisheries beginning in the 1920s. The fluctuations in these populations finally led to a crash of the Lake Erie lake herring **fishery** in the 1920s. The **fishery** there dropped from an earlier high harvest rate of around 32 million pounds (14.5 million kilograms) per year to a low of only 5.7 million pounds (2.6 million kilograms) per year. Similar declines in lake herring catches from lakes Huron and Michigan occurred in the 1930s, and again in the 1950s. Lake Superior's lake herring catch remained high until 1941, then declined. These declines were probably caused by overfishing and environmental degradation, particularly degradation of **spawning** areas in places such as Green Bay (Lake Michigan). After the smelt had become established by the 1930s and 1940s, it may have competed with or preyed upon lake herring, further influencing its decline, especially in Lake Michigan.

The cisco catch rates of the Great Lakes also experienced serious declines by the 1950s. As lake trout populations reached their final peak in the 1920s, their prey (ciscoes) decreased. Once the lake trout began its decline, numbers of ciscoes increased somewhat in the 1930s and 1940s. These fish were then exploited in sequential order from the largest species to the smaller species. Catches were high for a short time, in part because of higher populations and because fishermen shifted their efforts to ciscoes (particularly to bloaters). In the 1940s, cisco populations in Lakes Ontario and Huron collapsed due to a combination of overfishing, environmental degradation, and possible **competition** or predation by smelt and alewife. The cisco catch in lakes Superior and Michigan remained constant through the 1950s, but collapsed in the following decades.

Fishermen, as always, responded to declines in lake herring and ciscoes by switching their effort to other species. Perch catches in lakes Huron and Erie increased in the late 1920s and early 1930s. Eventually, smelt became so well established in the lakes that fishermen began to utilize them. A smelt **fishery** using trawl nets developed on the Great Lakes.

The story of the sea lamprey's effects on various fishes is intricate. Once the sea lamprey became established in a lake, the first declines occurred in the large, deepwater species such as lake trout, burbot and the largest of the deepwater ciscoes. These were the species upon which the sea lamprey was a **parasite**. Next, the sea lamprey occasionally preyed upon the other **coregonines** such as lake whitefish and lake herring. Walleye and bass also were preyed upon occasionally, and some sea lamprey attacked channel catfish and bullheads. As sea lamprey attacks increased, their prey declined. Because the numbers of large **predator** fish (mainly the lake trout) were declining, alewife were able to increase in abundance, especially in the waters of lakes Huron and Michigan. (Lake Superior and its tributaries were probably too cold for alewife to become as well-established.)

The alewife's story overlaps that of the sea lamprey. The alewife eats mainly large **plankton** just as the native lake herring do. As the alewife increased, the native lake herring and some other fishes decreased. The alewife, which travelled in dense schools, may have outcompeted the young of native species or simply preyed on their eggs and **fry**. Eventually, the alewife became predominant throughout the lakes.

Sea lamprey and alewife caused some of the most significant changes for the life of the lakes. Lake trout declined to a catch of less than 1,000 pounds (454 kilograms) in Lake Erie in 1937. Trout catches had already dropped in Saginaw Bay and Green Bay. Trout declined in Lake Huron in the late 1930s, and in Lake Superior in the 1940s. Finally, the lake trout **fishery** suffered a dramatic collapse in Lake Superior in the 1950s; fishermen switched back to lake herring, and their catch of this fish increased. Lake whitefish declined in the western basin of Lake Erie in the 1920s, and fishermen there switched to yellow perch. In Lake Michigan, lake whitefish had a resurgence in the 1920s, but the catch dropped again in the 1930s. By the 1930s, Lake Huron fishermen were noticing rapid drops in lake whitefish, and conflicts arose. Lake Superior continued its reputation as being somewhat isolated from and resistant to negative impacts — in the 1930s and 1940s a recovery of lake whitefish occurred there.

Other species showed dramatic effects during this era. In the 1930s, Lake Ontario's total **fish production** dropped behind even that of the historically less productive Lake Superior. In 1924, sauger in Lake Erie declined. Northern pike in Lake Erie had already declined by 1915, largely due to loss of wetland **spawning** areas. A notable subspecies of walleye in Lake Erie, the blue pike, had also begun serious population fluctuations around 1910; in the following era, this subspecies would become extinct. In summary, because of overfishing, invasion by sea lamprey and alewife, and environmental degradation, this era saw the end of the Great Lakes commercial **fishery** for some native species which had influenced coastal history.

Era of New Problems, New Management Objectives and Recovery (1950s to present)

Social Changes

After the St. Lawrence Seaway was completed in 1959, the Great Lakes were open to medium sized, international, ocean-going vessels. The region became a bigger player in the global marketplace, spurring further industrial growth and development. With this direct opening came problems, however. The industrial boom led to new, more insidious environmental degradation.

Eventually, the U.S. and Canada experienced a social reawakening. Environmental quality had become so poor that the environmental movement came hand-in-hand with the other social movements of the 1960s and 1970s. Environmental awareness about the Great Lakes increased when the mass media warned, "Lake Erie is dead." Rachel Carson's book, "Silent Spring," told of the newest threats to the environment: pesticides and other chemical **contaminants**. Environmental groups were formed, and sweeping reforms were made in national environmental legislation. The first Earth Day was held in 1970, mostly in response to the **eutrophication** of the Great Lakes. People spoke up for laws to make water "fishable, swimmable and drinkable."

Technological Changes

Along with the changes in shipping and global economies came other technological changes. The computer age began, allowing for more accurate navigation and processing of data. Fish finders soon became commonplace, even on individuals' recreational fishing boats. With industrial growth in the region came a vast array of industrial, agricultural and household chemical products. It would take some time before people realized the impacts such chemicals could have in the Great Lakes.

Environmental Changes

Exotic species continued to exert their influences in the Great Lakes. The effects of the sea lamprey worsened in the 1950s, until the first control efforts with lampricides began in 1958. The alewife had increased greatly. Massive die-offs of alewife began in the late 1950s and increased substantially in the 1960s, causing aesthetic problems on beaches. Other new invaders appeared years later in the Great Lakes, although this time these hitchhikers (such as the spiny water flea, zebra mussels and ruffe) rode in on trans-oceanic vessels.

Very serious and obvious problems due to cultural **eutrophication** attracted public attention to Great Lakes fisheries. Although stories reported the "death" of Lake Erie, actually it was too alive. The **eutrophication** process had brought nutrients into the lake and over-enriched its productivity. **Algae** bloomed and died; combinations of small aquatic life changed (for example, tubificid worms replaced the burrowing mayfly). Increased plant life meant more decay, particularly at the lake bottom. This decay led to lower oxygen levels in the **hypolimnion**, the bottom-most cold layer of water. All of these factors led to fish kills and obvious changes in the life of the lake.

The public was alarmed! While Lake Erie was the most affected of the lakes because of the shape of its basin, its shallowness, its greater pollution, and its southernmost location, the other lakes were beginning to experience some of the same serious changes, particularly in the bays. The shallows of the Great Lakes were important to Great Lakes fishes for **spawning** and early growth and important to human water supply, waste dilution, and recreation. These shallow, in-shore areas were the first to be affected by pollution from point sources (municipal treatment plants, industrial processes) and from nonpoint sources (agricultural runoff, household use of such products as detergents with **phosphates** and lawn/garden chemicals). By the end of this era, the public supported broad-ranging legislative initiatives in controlling some of these obvious sources of pollution. The lakes, including Lake Erie, began the process of recovery from nutrient overenrichment. They are now, in most ways, in better condition for humans and fishes than they were only a few decades ago.

Changes in the Great Lakes Fisheries

The changes in water quality and in the supply of invertebrate **benthic** fish foods due to **eutrophication** were felt in the fish populations of lakes Erie and Ontario. Warming, the lack of oxygen at the lake bottom in summer months, and the lack of burrowing mayflies and other **benthic** foods were particularly serious in the central basin of Lake Erie. By the late 1950s, these conditions in Lake Erie led to the collapse of lake whitefish. Walleye had also lost their important summer **habitat**, and commercial catches of this fish in Lake Erie declined by 1969 because of **habitat** loss and overfishing.

The blue pike in Lake Erie, a subspecies of walleye, had also lost its summer **habitat**. More importantly, though, it was overfished in the late 1940s when fishermen, trying to meet high demands for fish as protein during WWII, switched to blue pike from the declining lake herring and lake whitefish. The use of nylon nets and new fish-finder technologies in the 1950s aided in this overfishing. Numbers of blue pike dropped in the 1950s, and this fish became extinct, although some populations may have interbred with walleye.

Another problem, **stunting** (slow growth) of yellow perch, occurred in Green Bay and Saginaw Bay. This may have happened because of the lack of large **predators** to remove enough perch so that the remaining perch could grow and because burrowing mayflies (a food) were lost probably due to **contaminants** and/or low oxygen in the lake **sediments**.

Throughout the lakes, the decline of lake trout finally reached catastrophic levels. In Lake Ontario, the lake trout catch in 1964 dropped to less than 1,000 pounds (454 kilograms). Even in Lake Superior, the lake trout declined dramatically in the 1960s. The effects of predation by the sea lamprey and intensive fishing pressure with nylon gill nets were too much for populations to withstand. The only fishes left to support the Great Lakes commercial **fishery** by the 1960s were smelt, yellow perch and bloaters. White perch, an **exotic** which arrived in the 1950s, supported a small **fishery** in the Bay of Quinte on Lake Ontario.

In summary, by the 1960s, the total effect of human population growth and technological changes had taken their toll on and forever changed the Great Lakes fisheries. Many of these changes had occurred over a long time. In fact, some had their roots in the earliest technological changes at the beginning of the settlement and commercial fishing in the area. Social, technological (including overfishing), and environmental changes (such as modification of drainage basins due to forest cutting and settlement, invasions by marine and other **exotic** species, and cultural **eutrophication**) had profound impacts. Great Lakes fisheries changed in the following general ways:

1. native species were replaced with **exotic** species such as smelt and alewives, thus altering the forage base for the larger fish in the lakes;

2. a general, widespread decline of large **predators** such as lake trout, walleye, lake whitefish and burbot occurred, and formerly relatively stable fish populations changed; lakes Ontario and Erie and deepwater regions of lakes Superior, Huron and Michigan showed the greatest changes.

These changes in the fisheries demanded three types of drastic action: pollution control, sea lamprey control, and new directions for **fisheries management** were initiated throughout the region.

Pollution control and water quality standards established in the 1970s went a long way toward controlling those factors which had so altered fish **habitats** in the Great Lakes. The governments of Canada and the U.S. signed the first Great Lakes Water Quality Agreement in 1972. Under this agreement, each government agreed to reduce the inputs of phosphorus which had caused cultural **eutrophication** in the lakes. The International Joint Commission (IJC) was charged with overseeing progress in this area. In the U.S., pollution control and cleanup were carried out by several states in conjunction with the Environmental Protection Agency (EPA) according to the Federal Clean Water Act. New wastewater treatment plants were constructed, and **phosphate**s in detergents were banned in several states. In Canada, the Province of Ontario's Ministry of the Environment joined forces with Environment Canada to implement the agreement. These drastic measures resulted in greatly improved water quality in the Great Lakes and in additional Great Lakes water quality agreements to limit other **pollutants** in the basin.

The second set of drastic actions in the basin was spurred by the losses of fisheries due to the sea lamprey. In 1955, in one of the most important developments in Great Lakes **fisheries management**, the Great Lakes Fishery Commission (GLFC) was formed as a result of an international convention between the U.S. and Canada. The GLFC was established for two reasons:

1. to develop coordinated fisheries research programs which would help in the sustained productivity of fishes, particularly the native lake trout; and

2. to develop a program to eradicate or minimize sea lamprey in the lakes.

Around 1950, the U.S. Fish & Wildlife Service began research on the impacts of the sea lamprey in the Great Lakes. Field stations had been established at Hammond Bay on Lake Huron (in Michigan), at Marquette on Lake Superior (in Michigan), and at other locations (which were later closed). In 1956, another station was established at Ludington, Michigan on Lake Michigan. State, provincial and federal governments began cooperating on research; the establishment of the GLFC allowed fisheries managers to enter into a new era of international, broad-scale management.

The sea lamprey research soon began to pay off. Several years of extremely intensive research led to the discovery in 1957 of the chemical lampricide called TFM. By the 1960s and 1970s, many Great Lakes **tributary** streams had been treated successfully with TFM. The sea lamprey problem had come under control to some degree.

A third set of drastic actions further influenced the direction that Great Lakes fisheries were to take in the modern era. New **fisheries management** goals were needed to address the current situation of low native-fish populations, new **forage fishes** (some of which — namely alewives— were dying on beaches) and changing market demands. In 1966, the Michigan Department of Natural Resources (MDNR) began to take bold steps in changing the course of **fisheries management** toward a primary goal of establishing recreational fisheries. Over the next few years, the MDNR:

- prohibited the commercial harvest of lake trout and walleye in certain Michigan waters;
- regulated the commercial fishing effort by designating fishing zones and depths, banned gill nets for state-licensed fishermen, limited the number of licensed commercial fishermen, and established catch quotas and/or effort;
- shifted the commercial **fishery** (except for the tribal **fishery**) to the species less valued by sport anglers;
- decided to use the low value, smaller-sized fishes as a forage (food) base for desired sport fish;
- introduced Pacific salmon (coho salmon in 1966 and chinook salmon in 1967) and built hatcheries to continue these **stocking** efforts.

There was much discussion and controversy throughout the region as these broad sweeping changes were made. The Province of Ontario did not agree with this basic philosophy of introduction of **exotics** to manage other **exotics** (alewife and smelt) in the Great Lakes. Instead, Canadian Great Lakes **fisheries management** goals targeted native fishes, such as lake trout, and their **habitats**. Some U.S. states shared those goals, but eventually, to one extent or another, other Great Lakes states and the Province of Ontario began **stocking** Pacific salmon.

This shift in basic philosophy benefitted many millions of Great Lakes residents by giving them a chance to experience the Great Lakes fisheries through recreational fishing. This change also reflected the change to **Optimum Sustainable Yield (OSY)** as the basis for **fisheries management** decisions. OSY is defined as the blending of biological, social, economic and political values of a **fishery** to produce the optimum (most favorable or acceptable) benefits to society from fish **stocks**. This philosophy of management, which incorporates the needs of all stakeholders, is the current basis for management of Great Lakes fisheries.

Michigan Department of Natural Resources orders restricting commercial fisheries quickly put some commercial fishermen out of business. But this was an enterprise already in decline in the Great Lakes region due to declines in lake trout and other coldwater species. The loss of small-scale family fishing can be compared to the loss of the small family farms in the region. Family members converted to other enterprises and left the Great Lakes **fishery** and their traditions behind them. Fewer young people took up the traditional skills and lifeways of their parents. A few families were permitted to carry on their fishing activities in certain areas of the Great Lakes, including urban areas, under fisheries assessment programs established by resource management agencies. These fishermen continued their tradition of stewardship for fisheries by collecting age, growth and reproductive data to help agencies with management decision-making. Over time, however, aging fishermen have left the **fishery** and agencies have issued fewer commercial fishing permits. In spite of these declines, the remaining fishing operations are economically viable, and commercial fishing remains an important activity in the Great Lakes region.

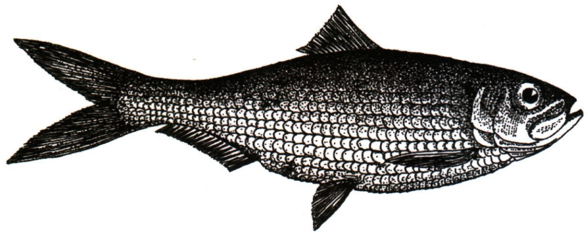
The change in management goals during the 1960s eventually affected treaty fishermen. From 1971 to 1979, a Native American fisherman named Abe LeBlanc set gill nets in an effort to challenge the restriction of treaty fishing rights. By 1979, this effort had reached the courts; the judge decided in favor of tribal fishing rights in ceded waters of lakes

Huron, Michigan and Superior. Further controversy arose over the use of gill nets; in 1980, the U.S. Court of Appeals agreed with the judge's decision that the state could not interfere with tribal fishing unless it could be shown that the **fishery** was in jeopardy. The U.S. Supreme Court agreed with this decision by declining to review it. This process assured the tribes' right to self-regulation of **fishery** resource use. In 1981, the tribes established the Chippewa-Ottawa Treaty Fishery Management Authority (COTFMA). This organization is responsible for establishing and enforcing fishing regulations for tribe members. This is done in cooperation with other **fisheries management** agencies and on the advice of the Inter-Tribal Fisheries and Assessment Program (which establishes harvest quotas, conducts fisheries research and does fisheries enhancement projects).

But controversy still raged because an important question remained undecided: how should the overall Great Lakes **fishery** resources be allocated among commercial and recreational users? In 1985, the state of Michigan, the tribes and the federal government arrived at a negotiated settlement called the "Entry of Consent Order," ordered into effect by the courts. In this 15-year agreement, tribes agreed not to fish in certain treaty waters which were important for sportfishing and regained exclusive commercial fishing rights in certain other waters. Treaty waters have been divided into three different types of zones: tribal fishing zones, zones for state-licensed commercial fishing, and lake trout refuges (**rehabilitation** zones). In refuges, gill netting and sportfishing for lake trout are not allowed. In addition to this system of management for the upper Great Lakes, a mechanism for resolving disputes was established. Also, a Technical Fishery Review Committee composed of COTFMA, U.S. Fish and Wildlife Service and Michigan Department of Natural Resources was established. This committee studies and establishes the total allowable catch (TAC) levels, population levels of fishes, catch and effort statistics for sport and commercial fisheries, and other important management data. Other state agencies, the Great Lakes Indian Fish and Wildlife Commission, and other tribal groups interact in a similar manner. Although current management structures have settled some of the major, emotional disputes, treaty fisheries issues exist today and will continue into the future.

"...no fresh waters known can, in any respect, bear comparison. They are inexhaustible, as to warrant the belief that, were a population of millions to inhabit the lakeshore, they would furnish...without any diminution...an ample supply."

19th Century Writer
from: The Life of the Lakes: The Great Lakes Fishery



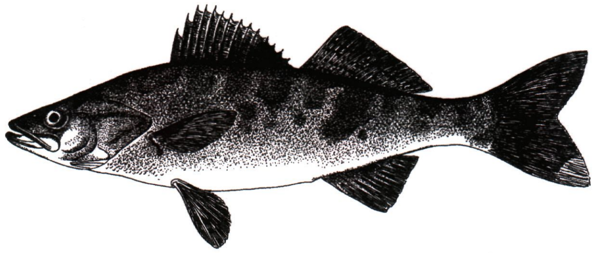
Alewife

(Alosa pseudoharengus)

Description: 6-8 in.; silvery, iridescent (shifting, rainbow-like color), single black spot behind head at eye level

Adult Diet: planktivore (**plankton**-eating); may also eat small fishes and fish eggs

Habitat/Behavior: mainly **pelagic**, but also inshore; **spawns** in shallows in late spring, early summer; strains **plankton** from water through structures called gill rakers (in gills); schools move inshore to feed at night; die-offs may occur in spring and summer; not native to Great Lakes — invaded from Atlantic Ocean through the Erie Canal into the Great Lakes



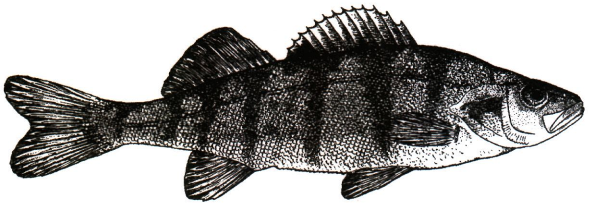
Walleye

(Stizostedion vitreum)

Description: usually 13-20 in.,1-3 lbs. but can grow much larger; dorsal fin with hard-rayed and soft-rayed sections; large eyes and white tip on tail

Adult Diet: piscivore (fish-eating)

Habitat/Behavior: **benthic**, deep **pelagic** and inshore; **spawn** in spring or early summer in rivers and lakes over coarse gravel or rocks; found in turbid areas and use plants, boulders, sunken trees for cover; feed at twilight or at night



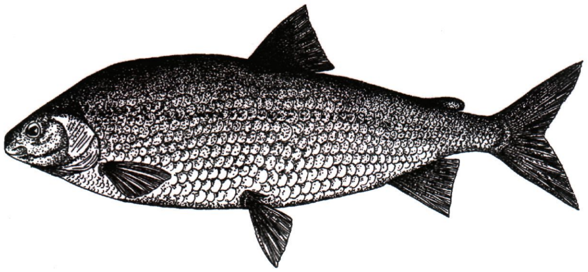
Yellow perch

(Perca flavescens)

Description: usually 4-10 in.; yellow belly and dark vertical bars on sides

Adult Diet: **forage fishes**, aquatic insects

Habitat/Behavior: **benthic** and inshore; **spawn** in late April through early May near aquatic plants



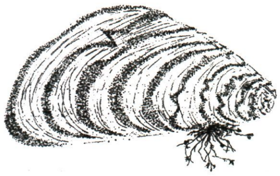
Lake whitefish

(Coregonus clupeaformis)

Description: usually 17-22 in., 1.5-4 lbs.; silvery with pale green-brown back

Adult Diet: planktivore, also some small fish and fish eggs

Habitat/Behavior: **benthic**; **spawn** in November and December usually in shallows; found in schools; found in **hypolimnion** in summer, and move to shoals in spring



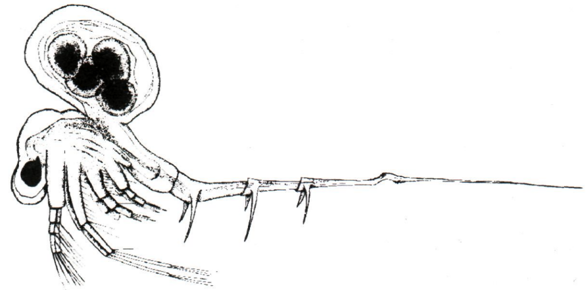
Zebra mussel

(Dreissena polymorpha)

Description: thumbnail sized mussel with light and dark bands

Adult Diet: filter-feeder on small particles and organisms in water

Habitat/Behavior: adults are **benthic** and attach to hard surfaces; usually found in clusters; larvae are **planktonic** (free-swimming, microscopic); not native to Great Lakes — arrived in Great Lakes in **ballast water** of international cargo vessel(s)



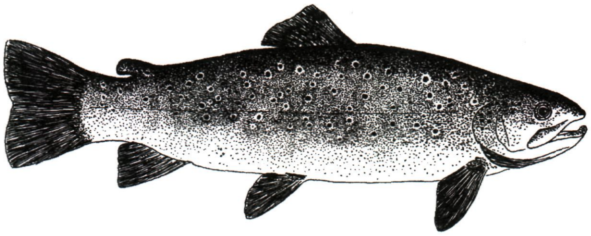
Spiny water flea

(Bythotrephes cederstroemi)

Description: about 1 cm. long; long, spiny tail; large, single eye

Adult Diet: predatory, pierces and shreds smaller **zooplankton** including *Daphnia*

Habitat/Behavior: **pelagic zooplankton** found in offshore areas; spine appears to serve as defense against **predators**; migrates to surface at night



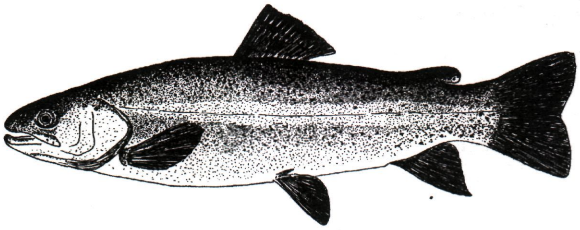
Brown trout

(Salmo trutta)

Description: usually 20-22 in. long but can grow much larger; 4-5 lbs; dark crosses or checks on silvery body, tail with occasional dark spots, 10-12 anal rays

Adult Diet: smelt, alewife, other **forage fishes**

Habitat/Behavior: **pelagic** (open-water) but also found in **benthic** and shallow inshore areas; *anadromous* (**spawn** in rivers, streams); **spawn** in late fall or early winter when 2-3 years old; do not die after **spawning**; not native — introduced into Great Lakes region



Rainbow trout or steelhead

(Oncorhynchus mykiss)

Description: usually 20-30 in. and 6-10 lbs.; light body with dark spots, side has pinkish band

Adult Diet: invertebrates, **plankton**, **forage fishes**

Habitat/Behavior: **pelagic** (open-water); *anadromous* (**spawn** in rivers, streams); enter rivers in late October through early May, and **spawn** from late December through the spring (but mostly in the spring); do not die after **spawning;** not native to the region — introduced from the Pacific

Great Lakes Fisheries: The Future

The Great Lakes fisheries of the future will experience many of the same challenges faced in the past — **pollutants, exotics,** changes in the status of certain fisheries, and the challenges of managing a vast international resource.

The Challenges of Pollutants and Contaminants

While the **eutrophication** problems of the 1960s and 1970s were literally blooming, another insidious challenge to **ecosystems** was developing. This was the challenge posed by other chemical **pollutants**. Many of the modern-day **pollutants** are not very visible or obvious; in fact, the **eutrophication** problems of the past partially masked the effects of these other **contaminants**.

Eventually, the presence of **contaminants** became known in the late 1960s and 1970s when people began to observe their effects on fish and wildlife. Some species, such as the bald eagle, had nearly disappeared from the Great Lakes region. Again an alarm sounded about environmental quality in the region.

Meanwhile, scientists developed instruments which allowed them to measure smaller and smaller concentrations of chemical **contaminants** in water and in animal tissue. The main **contaminants** were DDT and other pesticides, **PCBs** and a variety of other chemicals used in manufacturing and agriculture or produced as by-products. **Persistent chemicals**, such as DDT, break down slowly over time. Some **contaminants**, such as DDT and **PCBs**, are fat-soluble and are stored in an animal's fatty tissue. While only trace amounts of these chemicals were present in the water, through the processes of bioaccumulation and **biomagnification** the living organisms of the lakes collected quantities that affected them.

Bioaccumulation is the process of buildup of a material in an organism's body throughout its lifetime. Different fish and wildlife species are more or less susceptible to **bioaccumulate** certain materials; for example, long-lived species such as bald eagles and lake trout have a longer time to **bioaccumulate** potentially harmful substances. In addition, species with relatively high body-fat content (such as lake trout) accumulate more fat-soluble **contaminants** such as **PCBs** than do other, less fatty organisms.

Biomagnification is the process by which concentrations of persistent **contaminants** are increased along a **food chain**. For example, when animals such as **zooplankton** eat **phytoplankton**, they also consume the **contaminants** that have accumulated in their food. **Contaminants** that are persistent and fat-soluble such as **PCBs** and DDT remain in the body of the animal. At the next **trophic level**, when fish eat **zooplankton**, they absorb all the **contaminants** that the tiny animal had received both from its food and the water environment. In each animal along the **food chain** the **contaminants** become more and more concentrated or biomagnify. **Consumers** such as eagles and humans can have concentrations of **contaminants** that are over one million times greater than the water concentration. Therefore, even very low environmental concentrations of certain **contaminants** may reach levels in top **predators** that may affect their health.

The use of DDT (as an insecticide) was banned in Great Lakes states between 1969 and 1971, then banned by the U.S. and Canada in 1972. The use and manufacture of the insecticides aldrin and dieldrin were banned in 1974. **PCBs** had been widely used in plastics, paints, electrical parts and transformers, carbonless copy paper, adhesives, fire retardants and lubricants in industrial machinery, commercial refrigeration units, inks, and carpets. Voluntary control of **PCBs** began in 1971, and their manufacture was banned in 1977. **PCBs**, however, still enter the environment through improper disposal of products containing **PCBs**, and airborne **PCBs** from distant sources still enter the Great Lakes basin. **Toxic** quantities of such **contaminants** as DDT and **PCBs** still remain in bottom **sediments** where these non-water-soluble chemicals settled. Disturbance of **sediments** by dredging, shipping activity, storms, and burrowing organisms could bring these **contaminants** back into the **food chain**.

Unfortunately, many of the areas of greatest contamination are of vital importance to the Great Lakes fisheries. Nearshore areas that provide critical **habitat** for fish **spawning** and for juvenile fishes are particularly vulnerable to **point source pollution** and to the input of **contaminants** from **tributary** rivers, runoff, and shoreline development. These **littoral** areas also are the most productive regions of the lakes, influencing their overall health and productivity. **Contaminants** in organisms in these nearshore areas influence the entire **food web** of the lake. In addition, most of the fishing occurs in the nearshore areas of the lake such as bays, connecting channels, and lower reaches of tributaries, thus bringing humans into more direct contact with potentially contaminated fishes.

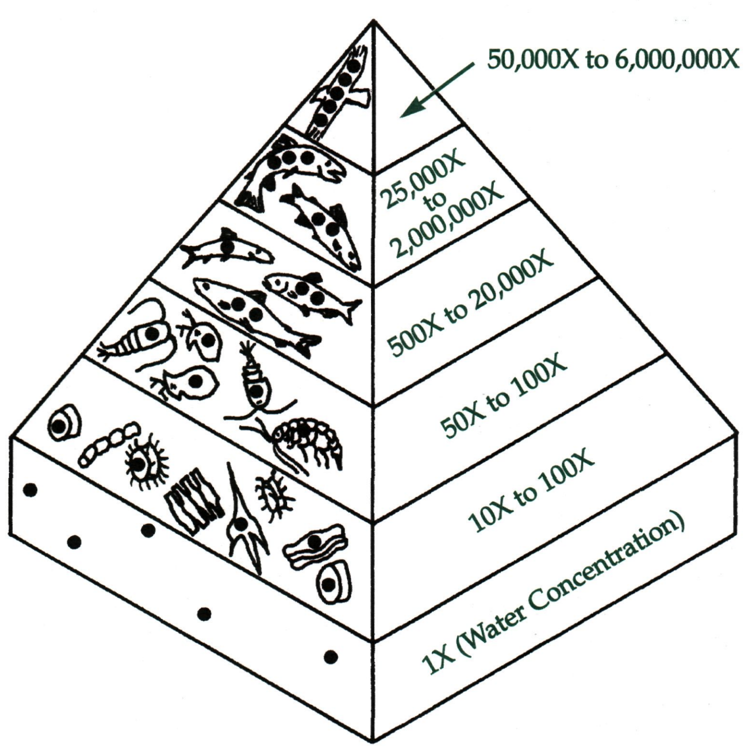
To deal with the contamination of fishes and possible human health risks, Great Lake states and the Province of Ontario issue fish consumption advisories. To establish these advisories, which guide anglers in their choices about eating fish, managers are beginning to use the science of **risk assessment**, a procedure used to estimate the probability of negative health effects from a specific source and at a particular exposure level. There are many different ways to conduct **risk assessments**; for example, methods developed by the EPA use estimates of increased cancer risks associated with specific amounts of contaminated fish consumed. Other agencies, such as the FDA, use an approach different from a **risk assessment** approach. In this "safe level" approach, fish over a given "action level" (such as fish with over 2 parts per million [2 ppm] of **PCBs**) are not to be sold in interstate commerce.

Each state then uses different assumptions about this **risk assessment** information to devise their **risk management** plan; this step incorporates the social, economic and political information to decide how to reduce or eliminate the potential risks to humans.

Thus a mosaic of fish consumption advisories exists for the Great Lakes region. To learn about the current fish consumption advisories for a given area of the Great Lakes, consult your state or provincial fishing regulations information. These advisories provide information on species and sizes of fish from certain bodies of water to avoid consuming or to minimize consumption. Advisories also provide information on which segments of the population (such as pregnant women, children) should minimize or avoid fish consumption.

Fish consumption advisories are risk management tools. They tell anglers how to minimize their risk of negative effects of **contaminants** by following certain fish preparation guidelines. Since many **contaminants,** including **PCBs**, are fat-soluble, ways to reduce exposure include trimming fatty tissue in the belly flap, around the lateral line and

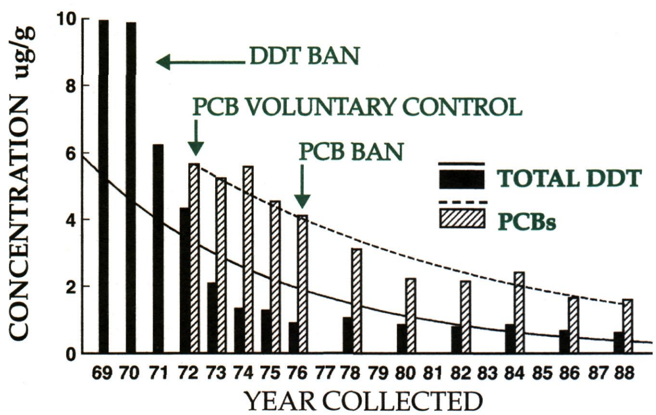
Biomagnification in the Great Lakes



Dots represent concentration of **contaminants** in organism. Concentrations are expressed as multiples of the water concentration at the right of the figure.

dorsal areas, and cooking the fish in such a way that the fat drains away from the fish (broiling, grilling). Recently, concentrations of **contaminants** in fish flesh have declined in most areas of the lakes.

Contaminant Trends in Lake Michigan Bloaters



Source: R. Hesselberg, National Biological Survey, Ann Arbor, MI.

Several studies are underway to learn about how eating contaminated fish affects humans. Some researchers believe that some **contaminants** may negatively influence infant birth weight and early childhood development; more recent studies, however, consider such factors as how much the mother smokes or drinks alcohol and did not find relationships between fish consumption levels and such effects on babies. Work continues on assessing the possible links between **contaminants** in many foods (not just fish) and cancer or reproductive effects on humans and wildlife. Long-term, more complex studies will provide scientists and managers with even better information in the future.

Meanwhile, the problem of what to do about **contaminants** still exists. While levels of some **contaminants** have declined by up to 90% in most areas since the 1970s, some (such as **PCBs**) are still entering the basin, and some remain in **sediments** and probably will for a long time. Further gains in pollution control and reduction of **nonpoint source pollution** will be more difficult than in the past and will come at a greater cost. Starting in 1987, new steps were taken to address these problems more specifically. The U.S. and Canada identified areas of the Great Lakes basin severely affected by pollution. Today each of these 43 **Areas of Concern** (AOCs) is developing a **Remedial Action Plan (RAP)** which takes a comprehensive approach to restoring the area's beneficial uses (such as fishing, swimming). These RAPs allow many different agencies, communities and individuals to work together to solve serious water quality problems within the AOCs. To get involved in this process, contact the International Joint Commission (see Appendix 1).

Questions regarding the future influence of **contaminants** on Great Lakes fisheries are many, including:

- What will future studies show about the relative risks of consuming various types of foods, including fish?
- How clean can people make the Great Lakes? Is it possible to achieve "zero discharge" of **contaminants** into the lakes? Are consumers willing to pay more for some products to achieve this?
- How will various wastes be disposed of in the future?
- How will contaminated **sediments** be managed?

Challenges Due to Exotic Species in the Great Lakes

The parade of **exotic** species entering the Great Lakes continues, and the management problems each new species presents also will continue.

Even the sea lamprey, which has been in the basin for decades, continues to present management challenges for fisheries biologists. In some areas of the lakes, for example northern Lake Huron, sea lamprey numbers and wounding rates on lake trout and salmon have increased in recent years. Reasons for this resurgence of sea lamprey may include improved water quality in **spawning** areas, recovery of a key prey species (the bloater), lack of sea lamprey control treatments in large systems such as the St. Marys River (because of prohibitively high costs), and reductions in funding for sea lamprey control in the region. The Great Lakes Fishery Commission is now refocusing its efforts in sea lamprey research, assessment and control. The pesticide TFM, long used in sea lamprey control, is due for reregistration with the U.S. EPA, which will require additional research on its use and effects. In addition, research into alternative control measures such as electric barriers and release of sterile males is underway. It is hoped that these alternatives will someday reduce the reliance on lampricides up to 50% or more.

Meanwhile, new, unwanted **exotic** species in the basin threaten to have as much or more impact than the sea lamprey has had. The invasion by the zebra mussel throughout the basin has caused some concern about future impacts on Great Lakes fisheries. Recent research in lakes Erie and St. Clair has found that as zebra mussels filter out **plankton** and nutrients, water clarity increases, but less food is available for the **planktonic** portion of the **food chain**. These changes may affect which fishes are present. Zebra mussels may also affect populations of native mussels in the Great Lakes basin. Some fishes have the type of tooth structures necessary to prey on mussels. These fishes include the freshwater drum, the redear sunfish, the pumpkinseed, the lake sturgeon, and the river and copper redhorses; these and other fishes may prey upon the zebra mussel more in the future. Currently, researchers are seeking effective and appropriate measures to control the zebra mussel in inshore areas.

Recent Invaders of the Great Lakes

LAKE	WHITE PERCH	RUFFE	SPINY WATER FLEA**	ZEBRA MUSSEL***
Ontario	1950*	–	1985	1989
Erie	1953*	–	1985	1988
Huron	1980*	–	1984	1990
Michigan	1990	–	1986	1989
Superior	–	1986	1987	1989

Source: *Hartman, 1988.
**Michigan Sea Grant College Program, 1991.
***U.S. Fish and Wildlife Service, 1992. Nonindigenous Aquatic Species Data Base. U.S. Dept. of Interior, National Fisheries Research Center, Gainesville, FL.

Another recent invader is the quagga mussel, a close relative of the zebra mussel. The quagga mussel is of concern because it tolerates cold, deep water; in deep water this mussel may have impacts similar to the shallow-water zebra mussel. The ruffe, a perch-like nonnative fish, has been found in Lake Superior near Duluth, Minnesota and Thunder Bay, Ontario and has moved as far as the Sand River in Wisconsin. Since it was first observed in 1986 in western Lake Superior, it has increased dramatically in numbers and may have competed with yellow perch and other native species, causing their declines. It may prey on lake whitefish eggs and have an impact on populations of this important fish. Researchers are making plans for reducing its numbers where it is found and are investigating various control methods such as the release of sterile males and chemical control. To try to prevent its spread to other regions, shippers have agreed to avoid dumping **ballast water** from the Duluth area into other parts of Lake Superior.

Not all potentially important invaders are larger animals. A **zooplankton** by the name of *Bythotrephes cederstroemi* (spiny water flea or "Bc") is now found throughout the Great Lakes. Like the zebra mussel, this **exotic** organism is believed to have made its way into the Great Lakes in the **ballast water** of foreign, ocean-going vessels. Bc is relatively large and has a long barbed spine (total length about 0.3 in./8 mm) making it difficult for small alewife, bloaters, yellow perch, lake trout and rainbow trout to ingest it. It is eaten by larger fishes. Bc itself is a **predator** on other **zooplankton.** The ultimate effects of Bc on the entire Great Lakes **food web** are unknown at this time, but research on this question is underway. It may reduce the availability of smaller **zooplankton** (such as *Daphnia*) that are important to young native fishes, such as bloaters.

The continual parade of **exotics** arriving in the Great Lakes will never be prevented. In fact, if, as some scientists predict, global warming occurs, the waters of the Great Lakes may become more hospitable to an even wider variety of potential invaders. Furthermore, once certain **exotic** species arrive and begin to thrive, complete eradication probably is not possible. Some measures, however, can be taken to slow these invasions. For example, most ships now exchange their **ballast water** before entering the St. Lawrence Seaway. This became mandatory in U.S. waters in 1992 and in Canadian waters during the 1994 shipping season. The questions surrounding effects of **exotic** species on Great Lakes fisheries will continue:

- What new species will arrive in the future?
- If global warming occurs, will it affect the water temperature of the Great Lakes and the quality of fish **habitats** such as coastal **wetlands** to the point where new **exotics** may become established?
- What will be the effects of Bc, zebra mussels, quagga mussels, and **exotic** fishes (such as the ruffe) on other native fishes, aquatic communities, and Great Lakes **ecosystems**?
- What control measures are most effective in reducing the populations of **exotics** to tolerable levels? What are the costs and benefits of various control measures? What levels of **exotics** are "tolerable" given costs of controls? Is the public willing to pay for such measures?

Challenges Due to Changes in the Status of Various Species

The status of certain fish species in the Great Lakes is always of concern. New challenges to fish **stocks** include the presence of bacterial kidney disease (BKD), and the decline of the forage base for salmonine populations.

BKD occurs mainly in Pacific salmon. It also occurs in other salmonid species such as brook trout. It has always been present in low levels in Great Lakes salmon. In the late 1980s, BKD was found in large numbers of chinook salmon and has been proposed as a cause of declines in the chinook, particularly in Lake Michigan. Fish with BKD show signs of bloating, internal bleeding, and susceptibility to other **parasites** and diseases. Some scientists now believe that certain environmental conditions may trigger the disease to become more common in fish and to have greater impacts on fish populations. Researchers are investigating ways of controlling or limiting the occurrence of BKD in hatchery-reared fish. BKD and its impacts have even caused fish managers to rethink the role of hatcheries in sustaining fish populations in the basin. Some managers believe that reduced reliance on hatchery fish for **stocking** will lead to more viable and resilient populations of wild-produced fish.

The status of **forage fishes** is now of great concern for fisheries managers throughout the Great Lakes basin. In lakes Michigan and Huron, alewife populations declined sharply through the 1980s. In Lake Superior, smelt declined and lake herring increased, but both of these fishes tend to fluctuate widely in numbers, possibly due to climate variations from year to year. In Lake Ontario, older and larger alewife and smelt have declined, there has been a decline in overall prey **biomass,** and the poor condition of alewife recently is thought to make them more susceptible to die-offs during extreme weather (cold winters). In fact, recent surveys show a dramatic decrease in Lake Ontario's forage **biomass** between 1991-92 and 1992-93. Although weather may play a role in influencing forage species' population levels, researchers and managers have hypothesized that high levels of **stocked** salmonids also played a role in reducing the forage base. Ironically, decreased **phytoplankton** abundance due to lake clean-up efforts and water quality improvements may also be linked to declines in the forage base.

The decline in forage **stocks** and the effects of BKD together may have contributed to declines in salmon in many areas of the lakes. In turn, recreational salmon fishing efforts and catches have decreased recently. The tentative conclusion most managers are reaching is that **stocking** programs for salmonids have reached their limits; most states and the Province of Ontario are now either reducing **stocking** levels or making plans to do so soon.

However, forage fish **ecology** is complex. In Lake Michigan, for example, as alewife declined, other **forage fishes**, including bloaters, have increased. Pacific salmon in Lake Michigan will make some use of these alternative **forage fishes**, but still seem to prefer alewives. The declines of **forage fishes** impact other parts of the **food web**, namely the quantities and types of **zooplankton**. The amounts of **zooplankton** available in turn affect the feeding habits and growth rates of juvenile fishes of a variety of species.

Scientists and managers are now sorting out the implications of these changes in the forage base for management of all Great Lakes fisheries. New sampling techniques will allow better estimates of the abundance of **forage fishes**. Questions about the forage base and the status of various fish populations will remain into the future:

• How can BKD be better managed to have a lesser impact on salmon populations in the Great Lakes? Or is BKD simply a symptom of populations stressed by lack of forage?

• What are the effects of BKD on naturally reproducing vs. hatchery-reared salmon? What are the implications for **stocking** programs?

• How can researchers and managers better assess the status of **forage fishes** in the Great Lakes? Can better models be developed to predict the sometimes wide fluctuations in forage fish populations?

• How should the forage base be better allocated among commercial fish species, **stocked** salmon, and naturally reproducing fishes?

• What are realistic goals for managing recreational salmon fisheries? What is the role of lake trout in Great Lakes fisheries? Are lake trout and salmon fisheries compatible?

Challenges Due to the Complex Number of Management and User Needs

Management of Great Lakes fisheries continues to be a complex task. Managing fisheries under a philosophy of **Optimum Sustainable Yield (OSY)** means trying to balance the interests of a variety of stakeholders. The fisheries are an international and multi-state resource. Their management also involves treaty arrangements with various tribal groups in the region.

Recently, federal agencies in the U.S. and Canada have made larger investments in **fisheries management** and research in the Great Lakes. For example, the U.S. Fish and Wildlife Service has recently taken a major role in coordinating federal and state activities under the Great Lakes Initiative, a program designed to address the goals of the Great Lakes Fish and Wildlife Restoration Act of 1990. For all of these agencies, reestablishing productive fish populations has been a primary emphasis in recent years. Yet, at present, the extent to which native fish communities can be restored, or the extent to which fish populations and **habitats** can be rehabilitated are unknown. State agencies, however, have placed greater emphasis than federal agencies on managing the Great Lakes fisheries for recreational fishing by **stocking** hatchery-reared fishes.

State agencies have responded, in part, to stakeholder demand for recreational fishing opportunities. Angler organizations have had strong voices in setting priorities for large salmonids in the region. Individual anglers also have a variety of expectations, some of which include **rehabilitation** of Great Lakes **ecosystems**. Recently, agencies have conducted research to better understand angler expectations, and more of this research will continue. In addition, helping anglers develop expectations based on quality fishing experiences (rather than quantity) and helping them develop catch-and-release fishing ethics and skills will become more common in the future.

Meanwhile, there is evidence that some fishes such as lake trout, steelhead, and even salmon are reproducing naturally in parts of the Great Lakes. Little is known about the potential impacts of this natural reproduction on forage **stocks**. This natural reproduction raises the question of how much relative investment should be made in hatchery rearing and **stocking** of these fish vs. protecting and improving **habitats** for "naturalized" fish populations. This question will receive increased discussion.

As in the past, environmental quality issues continue in the Great Lakes basin. **Wetlands** and coasts continue to be affected by development. Extending the winter navigation season, as proposed in the Great Lakes, may cause ice movements which would damage fish **habitats** along coasts. Providing structures that allow fish passage around hydroelectric dams on Great Lakes tributaries is also an issue.

In spite of the complexity of stakeholder expectations, resource issues, and agency structures and objectives in the region, something remains clear: change will always be a certainty. Yet some of the life of the lakes is amazingly resilient. Great Lakes fisheries will continue to serve as indicators of health and quality. Due to the value of the fisheries of the lakes, people have become much more involved in fisheries and environmental issues. In recent years, several agencies have conducted strategic planning for fisheries which broadens agency and citizen roles in management. For example, Ontario has recently completed its Strategic Plan for Ontario's Fisheries II. In its plans, the Great Lakes Fishery Commission has made a broader commitment to management efforts which protect biological diversity in the Great Lakes. The Great Lakes Fishery Commission and all **fisheries management** agencies of the Great Lakes basin in 1980 completed a Joint Strategic Plan for Management of Great Lakes Fisheries. This plan articulates a common vision for Great Lakes fisheries and provides strategies being implemented to work toward that vision. In the future, state, provincial and federal agencies will have an even greater need to work together and with citizens in formulating and carrying out a common vision for the Great Lakes fisheries and the "Life of the Lakes."

Factors Influencing Today's Great Lakes Fisheries

SOCIAL CHANGES

SETTLEMENT

- cultures mixing (native, European)
- later immigration
- today's population pressures
- urbanization

CHANGES IN VALUES OVER TIME

- subsistence
- developing markets in eastern U.S. and Canada
- rise of tourism and recreation
- global markets, economics
- changes in taste

SOCIOPOLITICAL CHANGES

- treaties
- policy changes: state, federal
- international cooperation (Canada, U.S.)

TECHNOLOGICAL CHANGES

LAND USE PATTERNS

- logging dam, canals

HARVEST AND OTHER TECHNOLOGIES

- nets, floats
- boats, engines
- radios, navigational equipment
- fish finders
- transport and refrigeration

MANAGEMENT SCIENCE TECHNOLOGIES

- hatcheries
- genetics
- modeling
- computers
- restrictions
- disease

ENVIRONMENTAL CHANGES

MODIFICATION OF DRAINAGE BASINS

EXOTICS

PHYSICAL/CHEMICAL MODIFICATIONS

- cultural eutrophication
- contaminants

ATMOSPHERIC AND GLOBAL CHANGES

- atmospheric deposition of contaminants
- global warming

How You Can Help Great Lakes Fisheries Into the Future

1. Become informed! Write for information, contact your state Sea Grant organization, (see Appendix 1), and get on organization and agency mailing lists. Read fisheries related information carefully. Support fisheries and water quality research and management. Recognize gains that have been made and challenges which lie ahead.
2. Visit fisheries-related sites; attend events that celebrate Great Lakes fisheries and water quality!
3. Join an organization and help influence that group to take a well-reasoned approach to fisheries issues.
4. Take part in activities to improve fisheries **habitat**. Help in clean-up projects, stream improvement projects or other such activities. Protect coastal **wetlands**—they provide important fisheries **habitats** in the Great Lakes. Join in efforts to help clean up one or more of the AOCs **(Areas of Concern)** in the Great Lakes. Get involved in the LaMPs process (Lakewide Management Plans).
5. Keep track of legislative issues and stay in touch with your state and national legislators.
6. Be an informed consumer. Learn about how to minimize your intake of **contaminants** by properly preparing your Great Lakes fish. Learn about various **contaminants,** and think critically about news stories you hear. Ask questions!
7. Take everyday actions to protect water quality – we are connected to the Great Lakes through **watersheds**. Choose, use and dispose of home and garden chemical products wisely. Dispose of used motor oil and other hazardous wastes properly.
8. Learn how to fish! If you already know how to fish, learn more about fish species, **fisheries management**, catch-and-release fishing. Promote fishing ethics.
9. Share your understanding of fisheries with others — in classrooms, youth clubs, local civic organizations.
10. Learn about the lifeways of those who fish: treaty, commercial and sport. Read stories, learn traditional skills (e.g., net making, knots, fish decoy carving); interview older community members about fishing or eating fish; learn arts related to fisheries (Great Lakes songs, etc.).

The Ethical Angler...

Abides by the Golden Rule.

• • •

Shows respect to others.

• • •

Shows respect for the resource by following laws and keeping only those fish that will be eaten.

• • •

Considers safety at all times.

• • •

Continually increases his/her knowledge.

• • •

Develops a personal fishery conservation ethic.

• • •

Takes a strong stand against littering and pollution.

• • •

Shares his/her knowledge and love of fishing.

• • •

Source: National Fishing Week packet, 1993.

"The lakes will never be at peace with us. There will always be new issues, new problems, new things to concern ourselves with."

John Magnuson
University of Wisconsin
from: The Life of the Lakes: The Great Lakes Fishery

Appendix 1

Agencies, Organizations and Educational Opportunities

Code for organizational areas of emphasis or responsibility

GLB = Great Lakes Basin
LS = Lake Superior
LM = Lake Michigan
LH = Lake Huron
LSC = Lake St. Clair
LE = Lake Erie
LO = Lake Ontario
SLR = St. Lawrence River

Fisheries Related Government Agencies

International

Great Lakes Fishery Commission – GLB
2100 Commonwealth Blvd., Suite 209
Ann Arbor, MI 48105-1563
313-662-3209

United States

National Biological Survey – GLB
U.S. Department of the Interior
1451 Green Road
Ann Arbor, MI 48105
313-994-3331

National Biological Survey – GLB
U.S. Department of the Interior
11188 Ray Road
Millersburg, MI 49759
517-734-4768

U.S. Fish and Wildlife Service
1849 C Street, NW
Washington, DC 20240

Great Lakes Coordination Office – GLB
U.S. Fish and Wildlife Service
1405 South Harrison Road, Room 308
East Lansing, MI 48823
517-337-6807

Ashland Fishery Resources Office – LS
U.S. Fish and Wildlife Service
2800 Lakeshore Drive East
Ashland, WI 54806
715-682-6185

Green Bay Fishery Resources Office – LM
U.S. Fish and Wildlife Service
1015 Challenger Court
Green Bay, WI 54311
414-433-3803

Alpena Fishery Resources Office – LH,LE
U.S. Fish and Wildlife Service
Federal Building, #203
145 Water Street
Alpena, MI 49707
517-356-3052

Lower Great Lakes Fishery Resources Office – LE,LO
U.S. Fish and Wildlife Service
405 North French Road
Amherst, NY 14228
716-691-5456

Canada

Department of Fisheries and Oceans – Canada – GLB
Canada Centre for Inland Waters
Public Information, P.O. Box 5050
Burlington, ON L7R 4A6
416-336-4871

Ontario Native Affairs Secretariat – GLB
10th Floor, Suite 1009
595 Bay Street
Toronto, ON M5C 2C2
416-326-4740

Tribal

The Great Lakes Indian Fish and Wildlife Commission – LS, LM, LH
P.O. Box 9
Odanah, WI 54861
715-682-6619

Chippewa-Ottawa Treaty Fishery Management Authority – LS, LM, LH
Albert (Big Abe) LeBlanc Building
186 E. Three Mile Rd.
Sault Ste. Marie, MI 49783
906-632-0043

Union of Ontario Indians – LS, LH
813 Danforth Avenue
Toronto, ON M4C 1J2
416-693-1305

Six Nations of the Grand River – LE
P.O. Box 5000
Oshweken, ON N0A 1M0
519-445-2201

Association of Iroquois and Allied Indians
R.R. #2
Southwold, ON N0L 2G0
519-434-2761

Provincial

Great Lakes Coordinator – LS, LH, LE, LO
Ontario Ministry of Natural Resources
Box 5000
Maple, ON L6A 1S9
416-832-7262

Lake Superior Unit – LS
Ontario Ministry of Natural Resources
P.O. Box 5000
435 James Street South
Thunder Bay, ON P7C 5G6
807-475-1375

Lake Huron Unit – LH
Ontario Ministry of Natural Resources
611 Ninth Avenue East
Owen Sound, ON N4K 3E4
519-371-5844

Lake Erie Unit – LE
Ontario Ministry of Natural Resources
P.O. Box 5463
659 Exeter Road
London, ON N6A 4L6
519-661-2734

Lake Ontario Unit – LO
Ontario Ministry of Natural Resources
1 Richmond Blvd.
Napanee, ON K7R 3S3
613-354-2173

State

Division of Fisheries – LM
Illinois Department of Conservation
524 South Second Street
Springfield, IL 62701-1787
217-782-6424

Division of Fish and Wildlife – LM
Indiana Department of Natural Resources
4021 West Washington Street, #C256
Indianapolis, IN 46204-2212
(317) 232-4080

Fisheries Division – LS, LM, LH, LE
Michigan Department of Natural Resources
P.O. Box 30028
Lansing, MI 48909
517-373-1280

Fisheries Section – LS
Minnesota Department of Natural Resources
500 Lafayette Road
St. Paul, MN 55146
612-296-3325

Great Lakes Fisheries Section – LE, LO
New York State Department of Environmental Conservation
50 Wolf Road
Albany, NY 12233
518-457-6937

Division of Wildlife – LE
Ohio Department of Natural Resources
Fountain Square, Building E-3
Columbus, OH 43224
614-265-6300

Bureau of Fisheries – LE
Pennsylvania Department of Environmental Resources
Office of Public Liaison
P.O. Box 1673
Harrisburg, PA 17120-2063
717-783-8303

Bureau of Fisheries Management – LS, LM
Wisconsin Department of Natural Resources
P.O. Box 7921
Madison, WI 53707
608-267-0796

Other Great Lakes Related Government Agencies

International

Information Services – GLB
International Joint Commission
Great Lakes Regional Office
P.O. Box 32869
Detroit, MI 48232
313-226-2170

United States

Great Lakes Commission – GLB
Argus II Building
400 South Fourth Street
Ann Arbor, MI 48103-4816
313-665-9135

Council of Great Lakes Governors – GLB
310 South Michigan Avenue, 10th Floor
Chicago, IL 60604
312-427-0092

U.S. Environmental Protection Agency – GLB
Great Lakes National Program Office
230 South Dearborn Street
Chicago, IL 60604
312-353-2117

U.S. Army Corps of Engineers
McNamara Building
477 Michigan Avenue
Detroit, MI 48231
313-226-4680

Canada

Environment Canada – GLB
Communications Directorate
25 St. Clair Avenue East, Room 600
Toronto, ON M4T 1M2
416-973-6467

Research Programs – Organizations

International Association for Great Lakes Research (IAGLR) – GLB
University of Michigan
2200 Bonisteel Blvd.
Ann Arbor, MI 48109
313-498-2007

International Association for Great Lakes Research (IAGLR) – GLB
University of Toronto, Scarborough Campus
1265 Military Trail
Scarborough, ON M1C 1A4
416-978-2011

Institute for Great Lakes Research – GLB
Bowling Green State University
12764 Levis Parkway
Perrysburg, OH 43551
419-874-3907

Great Lakes Research and Information Exchange Network – GLB
Great Lakes Consortium
SUNY-College of Environmental Science and Forestry
24 Bray Hall
Syracuse, NY 13210
315-470-6720

Great Lakes Research Consortium – GLB
214 Baker Laboratory, SUNY ESF
Syracuse, NY 13210
315-470-6894

Great Lakes Institute – GLB
University of Windsor
Windsor, ON N9B 3P4
519-253-4232

Great Lakes Environmental Research Laboratory – GLB
2205 Commonwealth Blvd.
Ann Arbor, MI 48105-1593
313-668-2235

Cooperative Institute for Limnology and Ecosystems Research (CILER) – GLB
University of Michigan
2200 Bonisteel Blvd.
Ann Arbor, MI 48109
313-764-2426

Center for Great Lakes and Aquatic Sciences – GLB
University of Michigan
2200 Bonisteel Blvd.
Ann Arbor, MI 48109
313-763-3515

Illinois-Indiana Sea Grant Program – LM
University of Illinois
104 Huff Hall
1206 South Fourth Street
Champaign, IL 61820
217-333-1824

Michigan Sea Grant College Program – LS, LM, LH, LE
University of Michigan
2200 Bonisteel Blvd.
Ann Arbor, MI 48109
313-763-1437

Department of Fisheries and Wildlife – LS, LM, LH, LE
13 Natural Resources Bldg.
Michigan State University
East Lansing, MI 48824-1222
517-355-4477

Minnesota Sea Grant College Program – LS
University of Minnesota
208 Washburn Hall
2305 East 5th Street
Duluth, MN 55812
218-726-8106

New York Sea Grant Institute – LE, LO
Dutchess Hall
SUNY at Stony Brook
Stony Brook, NY 11794-5001
516-632-6905

Department of Natural Resources – LO
Cornell University
Fernow Hall
Ithaca, NY 14853
607-255-2814

Lower Great Lakes Fishery Resources Office – LE, LO
U.S. Fish and Wildlife Service
c/o SUNY College at Buffalo
Science Room 253
1300 Elmwood Avenue
Buffalo, NY 14222
716-881-3151

Great Lakes Program Office – LE, LO
207 Jarvis Hall
State University of New York
Buffalo, NY 14260
716-645-2088

Ohio Sea Grant College Program – LE
The Ohio State University
1314 Kinnear Road
Columbus, OH 43212-1194
614-292-8949

The Pennsylvania State University – LE
Environmental Resources Research Institute
Land and Water Research Building
University Park, PA 16802
814-865-4700

Sea Grant Institute – LS, LM
University of Wisconsin-Madison
1800 University Avenue
Madison, WI 53705
608-263-3259

University of Wisconsin-Milwaukee – LS, LM
Great Lakes Research Facility
600 East Greenfield Avenue
Milwaukee, WI 53204-2944
414-227-3291

University of Wisconsin Extension – LS, LM
Environmental Research Center
1450 Linden Drive
Madison, WI 53706
608-262-2106

University of Wisconsin – LS, LM
Institute of Environmental Studies
550 North Park Street
Madison, WI 53706
608-262-5957

American Fisheries Society – GLB
5410 Grosvenor Lane
Bethesda, MD 20814

Rawson Academy of Aquatic Sciences – GLB
1 Nicholas Street, Suite 404
Ottawa, ON K1N 7B7
613-563-2636

Fisheries Related Organizations

National

American Sportfishing Association – GLB
1033 North Fairfax Street
Alexandria, VA 22314
703-519-9691

Canadian National Sport Fishing Foundation – GLB
366 Church Street
Oakville, ON L6J 1P2
416-847-8534

Trout Unlimited* – GLB
Suite 250
800 Follin Lane, SE
Vienna, VA 22180-4959
703-281-1100

Trout Unlimited* – GLB
3500 Eglinton Avenue East
Toronto, ON M6M 1V3
416-766-8233

The Izaak Walton League of America, Inc.* – GLB
1401 Wilson Blvd, Level B
Arlington, VA 22209
703-528-1818

Izaak Walton Fly Fishermen's Club – GLB
2857 Derry Road, Suite 604
Mississauga, ON L4T 1A6
416-855-9569

National Fisheries Institute – GLB
1525 Wilson Boulevard – Suite 500
Arlington, VA 22209
703-524-8880

National Wildlife Federation – GLB
8925 Leesburg Pike (Laurel Ridge)
Vienna, VA 22184-0001
1-800-435-3543

Canadian Wildlife Federation – GLB
2740 Queensview
Ottawa, ON K2B 1A2
613-721-2286
1-800-565-6305 *in Canada*

Muskies Canada
54 Peach Willoway
Willowdale, ON M2J 2B6

Regional

Great Lakes Sportfishing Council – GLB
P.O. Box 297
Elmhurst, IL 60126
312-941-1351

National Wildlife Federation – GLB
Great Lakes Natural Resources Office
506 East Liberty
Ann Arbor, MI 48104-2210
313-769-3351

Provincial

Ontario Charter Boat Association – LS, LH, LE, LO
88 Canmore Blvd.
Scarborough, ON M1C 3T8
Phone 416-282-5580

Ontario Federation of Anglers and Hunters – LS, LH, LE, LO
Box 2800
Peterborough, ON K9J 8L5
705-748-6324

* Call for local information

Ontario Fish Producers Association – LS, LH, LE, LO
Box 2129
120 Ellen Street
Blenheim, ON N0P 1A0

Lake Erie Fish Packers & Processors Association – LE
P.O. Box 153
Brieau, ON N0P 1N0
519-676-8752

Federation of Ontario Cottagers Association – GLB
215 Morrish Road, Suite 101
Scarborough, ON M1C 1E9
416-284-2305

Ontario Aquaculture Association
P.O. Box 234
Elmira, ON N3B 2Z6
519-775-5604

Sustainable Fisheries Network
Suite 404-B One Nicholas Street
Ottawa, ON K1N 7B7

State

Illinois

Illinois Wildlife Federation – LM
123 South Chicago Street
Rossville, IL 60963

Salmon Unlimited – LM
4548 North Milwaukee
Chicago, IL 60630
312-736-5757

Midwest Charter Boat Association – LM
7410 North Olcott
Chicago, IL 60648

Illinois Steelheaders – LM
1309 Hull
Westchester, IL 60154

Illinois Charter Captains Association –LM
11992 Louisa Road
Lena, IL 61048

Midwest Musky
10823 West 191st
Mokena, IL 60446

Indiana

Indiana Wildlife Federation – LM
319 East Carmel Drive
Suite G-200
Carmel, IN 46032

Lake Michigan Sportfishing Coalition – LM
P.O. Box 1312
Valparaiso, IN 46384

Michigan

Michigan Steelhead and Salmon Fishermen's Association – LM, LH, LE
P.O. Box 213
Paw Paw, MI 49079

Michigan Bass Chapter Federation – LS, LM, LH, LE
3700 Ronald
Lansing, MI 48910
517-485-7141

Michigan Council of Trout Unlimited – LS, LM, LH, LE
MICHIGAN TROUT
442 Fox River Drive
Bloomfield Hills, MI 48304

Michigan United Conservation Clubs – LS, LM, LH, LE
2101 Wood Street
P.O. Box 30235
Lansing, MI 48909
517-371-1041

Michigan Charter Boat Association – LS, LM, LH, LE
P.O. Box 80323
Lansing, MI 48908-0323

Michigan Fish Producers Association – LS, LM, LH
9140 00.25 Road
Garden, MI 49835

Michigan Fish Growers Association
19465 200th Avenue
Big Rapids, MI 49307

Great Lakes Offshore Fishing Club
327 North Butler
Lansing, MI 48915

Minnesota

Minnesota Conservation Federation – LS
1036-B S. Cleveland Avenue
St. Paul, MN 55108

Minnesota Sportfishing Congress – LS
Lake Superior Representative
4014 Emerson Road
Duluth, MN 55803

Western Lake Superior Trollers Association – LS
P.O. Box 7061
Duluth, MN 55807

North Shore Charter Captains Association – LS
1446 Highway 61 East
Two Harbors, MN 55616
(218) 226-4100

Lake Superior Steelhead Association – LS
P.O. Box 16034
Duluth, MN 55816-0034

T.R.O.U.T. (Together Reach Out Upgrade Trout) – LS
P.O. Box 7155
Duluth, MN 55807

New York

Lake Ontario Charterboat Association – LO
290 Winfield Road
Rochester, NY 14622

Lake Ontario Trout & Salmon Association – LO
P.O. Box 64
Newtane, NY 14108

Lake Erie Salmon and Trout Association – LE
446 Lake Shore Drive, NW
Dunkirk, NY 14048

New York Charter Sportfishing Council – LO
177 Sherwood Drive
Hilton, NY 14468

Oswego Maritime Foundation – LO
McCrobie Building
Lake Street
Oswego, NY 13126

Ohio

League of Ohio Sportsmen – LE
3953 Indianola Avenue
Columbus, OH 43214

Publishing Services Corporation – GLB
c/o Great Lakes Fisherman
P.O. Box 06355
Columbus, OH 43206-0355

Lake Erie Charterboat Association – LE
911 Pine Street
Perrysburg, OH 43551

Ohio Sport Fishing Federation – LE
7897 King Memorial
Mentor, OH 44060

Pennsylvania

Pennsylvania Federation of Sportsmen's Clubs, Inc. – LE
2426 North Second Street
Harrisburg, PA 17110
717-232-3480

Lake Erie Downriggers, Inc. – LE
P.O. Box 462
Erie, PA 16512

Pennsylvania Lake Erie Charter Captains Association
4225 Buffalo Road
Erie, PA 16510-2111

Wisconsin

Wisconsin Wildlife Federation – LS, LM
11 West Parkway
Oshkosh, WI 54901
414-642-7424

Great Lakes Sport Fishermen
P.O. Box 93188
Milwaukee, WI 53202

Wisconsin Charter Fishing Industries
120 Lennox
Neenah, WI 54956

Steelhead Inc.
P.O. Box 85
Brule, WI 54820

Salmon Unlimited Wisconsin
P.O. Box 08133
Racine, WI 53405

Other Citizen Organizations

Regional

Great Lakes United – GLB
State University College at Buffalo
Cassety Hall
1300 Elmwood Avenue
Buffalo, NY 14260

Great Lakes United – GLB
P.O. Box 548, Station A
Windsor, ON N9A 6M6
519-255-7141

Lake Michigan Federation – LM
49 East VanBuren, Suite 2215
Chicago, IL 60605
312-939-0838

Lake Superior Center – LS
353 Harbor Drive
Duluth, MN 55802
218-720-3033

Fisheries Educational Opportunities

Museums

Dossin Great Lakes Museum – GLB
100 Strand on Belle Isle
Detroit, MI 48207
313-267-6440

Marine Museum of the Great Lakes at Kingston – GLB
55 Ontario Street
Kingston, ON K7L 2Y2
613-542-2261

John G. Shedd Aquarium – GLB
1200 South Lake Shore Drive
Chicago, IL 60605
312-939-2426 ext. 3374

S.S. Keewatin – LM
P.O. Box 511
Douglas, MI 49406
616-857-2107

Northwest Michigan Maritime Museum – LM
324 Main Street
Frankfort, MI 49635
616-352-4122

Michigan Maritime Museum – LM
260 Dyckman
P.O. Box 534
South Haven, MI 49090
616-637-8078

Mackinac Point Lighthouse Museum
P.O. Box 873
Mackinac City, MI 49701

Beaver Island Marine Museum – LM
P.O. Box 263
St. James, MI 49782
616-448-2254

Niagara Falls Aquarium – LO, LE
701 Whirlpool Street
Niagra Falls, NY 14301
716-285-3575

St. Lawrence Aquarium and Ecological Center Inc. – SLR
41 Main Street
P.O. Box 87
Massena, NY 13662
315-769-0787

Manitowoc Maritime Museum – LM
75 Maritime Drive
Manitowoc, WI 54220-6843
414-684-0218

Fort William Historical Park – LS
Vickers Heights
P.O. Thunder Bay
Thunder Bay, ON P0T 2Z0

Edison Fishery – LS
Isle Royale National Park
Park Headquarters
Houghton, MI 49931
906-486-0986

Fishing Village Museum
Washington Island, WI 54246

Rogers Street Fishing Village Museum & Great Lakes Coast Guard Museum – GLB
2022 Jackson Street
Two Rivers, WI 54241
414-793-5905

Commercial Fishing Museum – LS
Brian Tofte
100 Hays Circle
Silver Bay, MN
218-226-4609

Fishtown National Historic Site
P.O. Box 406
Leland, MI 49654

Hatcheries and Weirs

Fishing Information Line – LS, LM, LH, LE
Michigan Department of Natural Resources
Lansing, MI
517-373-0908

Marquette State Fish Hatchery and Station – LS
488 Cherry Creek Road
Marquette, MI 49855
906-249-1611

Michigan Fisheries Interpretive Center – LS, LM, LH, LE
34270 C.R. 652, Route 1
Mattawan, MI 49071
616-668-3388

Fish Health Lab – LM
Wolf Lake State Fish Hatchery
34270 C.R. 652
Mattawan, MI 49071
616-668-2132

Thompson State Fish Hatchery – LM
Route 2, Box 2555
Manistique, MI 49854
906-341-5587

Platte River State Fish Hatchery – LM
15200 Honor Hwy.
Beulah, MI 49617
616-325-4611

Charlevoix Fisheries Station – LM
Box 205
Charlevoix, MI 49720
616-547-2914

Hunt Creek Fisheries Station – LM
Route 2
Box 2299
Lewiston, MI 49756
517-786-2613

Oden State Fish Hatchery – LM
3377 1/2 Oden Rd.
Oden, MI 49764
616-347-4689

Alpena Fisheries Station – LH
R#6, M-32
Alpena, MI 49707
517-354-2209

Harietta Fish Hatchery – LM
6801 Thirty Mile Road
Harietta, MI 49638
616-389-2211

Lake St. Clair Fisheries Station – LSC
Mt. Clemens, MI 48045
313-465-4771

Programs

Fish Ways
Ontario Ministry of Natural Resources
Resource Development and Stewardship Branch
Box 7000
Peterborough, ON K9J 8M5
705-740-1529

Aquatic Project Wild
1673 Carling Avenue
Ottawa, ON T5K 2G6
613-997-1095

CBC (Canadian Broadcasting Corporation) Enterprises
Educational Resources
Box 500, Station A
Toronto, ON M5W 1E6
416-205-3500

Future Fishermen Foundation
1250 Grove Avenue, Suite 300
Barrington, IL 60010
708-381-4061

National Fishing Week Steering Committee
2944 Patrick Henry Drive, Suite 15
Falls Church, VA 22044

Great Lakes Historical Society – GLB
480 Main Street
Vermilion, OH 44089
216-967-3467

MinnAqua Program
Minnesota Extension Service
4-H Youth Development
1420 Eckles Avenue
St. Paul, MN 55108

Center for Environmental Information – GLB
33 South Washington Street
Rochester, NY 14608
716-262-2870

Sea Grant Extension/Advisory Service Programs

Marine Advisory Program – LM
Illinois-Indiana Sea Grant Program
2320 West Peterson Avenue – Suite 200
Chicago, IL 60659
312-761-5099

Marine Advisory Program – LM
Illinois-Indiana Sea Grant Program
Department of Forestry and Natural Resources
1200 Forest Products Building
West LaFayette, IN 47907-1200
317-494-3625

Michigan Sea Grant Extension – LS, LM
MSU – UP
1030 Wright Street
Marquette, MI 49855
906-228-4830

Michigan Sea Grant Extension – LS, LM, LH
300 Court Street
Sault Ste. Marie, MI 49783
906-635-6368

Michigan Sea Grant Extension – LM
MSU Extension
Grand Traverse County Extension Office
2200 Dendrinos Drive, Suite 7
Traverse City, MI 49684
616-922-4260

Michigan Sea Grant Extension – LM
MSU Extension
333 Clinton Street
Grand Haven, MI 49417
616-846-8250

Michigan Sea Grant Extension – LH
MSU Extension
P.O. Box 599
Tawas City, MI 48764
517-362-3449

Michigan Sea Grant Extension – LH, LE
MSU Extension
21855 Dunham Road
Clinton Township, MI 48036
313-469-6085

Minnesota Sea Grant Extension – LS
University of Minnesota
208 Washburn Hall
2305 East 5th Street
Duluth, MN 55812
218-726-8106

New York Sea Grant Extension Program – LE
21 South Grove Street
East Aurora, NY 1405
716-652-5453

New York Sea Grant Extension – LO
Hartwell Hall
SUNY College at Brockport
Brockport, NY 14420-2928
716-395-2638

New York Sea Grant Extension Program – LE, LO
Cornell University
12 Fenow Hall
Ithaca, NY 14853-3001
607-255-2832

New York Sea Grant – LO
Swetman Hall
SUNY Oswego
Oswego, NY 13126-3599
315-341-3042

Ohio Sea Grant Extension – LE
The Ohio State University
Camp Perry, Bldg. 3, Room 12
Port Clinton, OH 43452
419-635-4117

Ohio Sea Grant Extension – LE
The Ohio State University
Lorain County Extension Office
42110 Russia Road
Elyria, OH 44035
216-322-0127

Ohio Sea Grant Extension – LE
The Ohio State University
Lake County Extension Office
99 East Erie Street
Painesville, OH 44077
216-357-2582

Ohio Sea Grant Education Program – LE
The Ohio State University
059 Ramseyer, 29 West Woodruff
Columbus, OH 43210-1085
614-292-1078

Wisconsin Sea Grant Advisory Services – LS
University of Wisconsin-Superior
143 Sundquist Hall
Superior, WI 54880-9985
715-394-8472

Wisconsin Sea Grant Advisory Services – LM
University of Wisconsin-Green Bay
ES-105
Green Bay, WI 54311-7001
414-465-2795

Wisconsin Sea Grant Advisory Services – LM
University of Wisconsin Center-Manitowoc County
Manitowoc, WI 54220
414-683-4700

Wisconsin Sea Grant Advisory Services – LM
University of Wisconsin-Milwaukee
Great Lakes Research Facility
600 East Greenfield Avenue
Milwaukee, WI 53204-2944
414-227-3291

Appendix 2

Glossary

abiotic: (AY-BYE-ah-tick) nonliving.

algae: (AL-gee) simple, photosynthetic plants that lack true roots, stems, or leaves.

algal blooms: large growths of algae in a body of water.

anadromous: (a-NAD-ra-muss) fish that migrate up river to spawn, but live in lakes (or oceans) as adults.

aquaculture: the cultivation of aquatic plants or animals.

Areas of Concern: severely polluted areas of the Great Lakes that have been designated by the International Joint Commission for clean-up effort upon recommendation by state/provincial officials.

ballast water: water held in a boat or large vessel to help balance it.

benthic: refers to animals and plants that live in or on the bottom of a lake or sea.

bioaccumulate: the build-up of a substance in a plant or in an animal's body.

biomagnification: the process by which concentrations of contaminants in plants and in animals are increased along a food chain; organisms (e.g., consumers) at higher trophic levels have higher concentrations.

biomass: the total mass of all living things in a given area.

carrying capacity: the maximum number of individuals of a species that can be supported in a given area or habitat over an extended period of time.

common property resource: a resource owned not by individuals but by the general public and managed by the government on the public's behalf.

community: an interacting group of different plants and animals.

competition: an interaction between two or more individuals or species that require the same limited resource to survive; this interaction can be harmful to one or more of the organisms.

consumer: organisms that eat other organisms or plants for nourishment.

contaminant: a chemical substance that is not naturally found in the environment, usually made by humans.

coregonines: (kor-eh-GO-neens) lake whitefish and their relatives including herring and deepwater ciscoes (chubs).

detrital rain: dead algae and zooplankton that sink down to lower levels from upper layers of water.

detritivore: (deh-TRY-ti-vore) small animal which feeds on decomposing matter and organic debris.

detritus: (di-TRY-tus) organic material that is either waste material from an organism or decomposing plants and animals.

diatoms: (DY-ah-toms) single-celled plants with hard "shells" of silica.

ecology: the study of the interrelationships between organisms and their environment.

ecosystem: all the animals, plants and environmental factors that interact within a system; the living and nonliving parts of the environment that interact.

epilimnion: (EP-ah-LIM-nee-on) the warmer, buoyant top layer of water in a lake during summer stratification.

exotic: not native; not originally found in that area, and usually brought in by humans, either by accident or on purpose.

eutrophic: (yoo-TROF-ick) a water body that is rich in nutrients and has high productivity – often turbid, with algal blooms and periodic decreases in dissolved oxygen.

eutrophication: (yoo-TROF-i-KAY-shun) the process through which waters become eutrophic.

fishery: the complex interactions between fish population(s) being used, the humans using it, and the environment of each.

fisheries management: the manipulation of people, aquatic populations, and/or habitats in an effort to obtain the goals desired for that aquatic population or ecosystem by its human members.

fisheries science: the scientific study of aquatic (water-related) living resources of the world; the study of the structure, the dynamics (or changes), the interactions of habitat, the aquatic organisms, and humans in order to achieve the goals set for that resource by humans.

fish production: the amount of new biomass of a given fish species in a given area over a given period of time.

food chain: the chain of organisms which feed, in turn, on each other and through which energy is passed on from one organism to another.

food web: a set of food chains intersecting and overlapping each other.

forage fishes: small fishes that are preyed upon by larger fishes; i.e. bloaters, lake herring, sculpins, alewife, smelt, and the juveniles of larger fish.

fry: newly-hatched young fish.

habitat: an area that provides life requirements such as food, shelter and space for a particular organism.

hypolimnion: (hi-po-LIM-nee-an) colder, denser water located at the bottom of a lake during summer stratification.

landed value: price paid to fishers for fish prior to processing, wholesaling or retailing.

limnology/limnologist: (lim-NOL-ah-gee) the study of/person who studies freshwater bodies/ecosystems (ponds, lakes and streams) and the relationships between their inhabitants and their environment.

littoral: (LIT-ah-rahl) the area near the shore that is shallow enough for light to be able to penetrate the water, reach the lake bottom and allow rooted plants to grow.

macroinvertebrates: a small animal, able to be seen with the naked eye, that does not have a backbone.

Maximum Sustainable Yield (MSY): to produce the greatest number of pounds of fish over a given time with a given level of fishing effort; this is done by determining the requirements of fish and the productivity of the environment.

mesh size: the size of the open spaces between the cords of a net.

mesotrophic: a water body that has a moderate amount of nutrients and a moderate production of organic matter; midway between oligotrophic and eutrophic.

metalimnion: (met-ah-LIM-nee-an) water layer between epilimnion (warm, top layer) and hypolimnion (cold, bottom layer), where temperature drop-off is greatest.

nonpoint source pollution: pollutants that do not enter the lakes at a single confined source, but rather from diffuse multiple sources such as agricultural runoff, road salt and acid rain.

oligotrophic: (o-li-go-TRO-fik) waters that are low in nutrients and in productivity and are often cold and deep.

Optimum Sustainable Yield (OSY): harvest level for a species that achieves the greatest benefit, economically, socially, and biologically.

parasite: an organism that lives in or on another living organism (host) and receives nourishment from it, but gives nothing to the host organism in return.

PCB: polychlorinated biphenyl; a type of persistent hydrocarbon that is toxic to some organisms and bioaccumulates.

pelagic: (pah-LAJ-ik) the open-water area of a lake.

percids: members of the perch family including yellow perch, walleye and sauger.

persistent chemicals: chemicals that are not decomposed in the environment. Many persistent chemicals accumulate in the tissues of animals as they eat contaminated prey.

phosphate: chemical nutrient containing phosphorus that can be found in agricultural or industrial runoff, household wastewater and stormwater that accelerates the eutrophication of a body of water.

phytoplankton: (FYE-toe-PLANGK-ton) small free floating plants, including algae, diatoms and cyanobacteria.

piscivorous: (pi-SIEVE-er-us) fish-eating.

plankton: (PLANGK-ton) plants or animals that inhabit lake or sea and drift with the currents; they may have some abilities to move; they range in size from single-celled plants or animals to large jellyfish.

planktivorous: plankton-eating.

point source pollution: pollution that has a distinct and identifiable source; it usually comes from a single pipe or series of pipes.

pollutant: a contaminant or natural substance present in large enough quantities to cause a problem.

predator: a species that lives by killing and eating other prey species.

producer: converts and stores the sun's energy and nonliving materials into living biomass (tissue), which is then available to other organisms in the food chain.

reef: a ridge of rock or sand at or near the surface of the water that provides habitat for many aquatic plants and animals.

rehabilitation: the repair of degraded aquatic ecosystems to increase their ability to sustain aquatic communities and provide benefits to society.

Remedial Action Plan: a plan to restore water quality in a severely polluted Area of Concern (AOC).

restoration: to return to nearly its former condition or status.

risk assessment: procedure used to estimate the probability of negative effects from a specific source of a contaminant and at a particular exposure level.

risk management: the process of incorporating social, economic and political information with risk assessment information to decide how to reduce or eliminate potential risks for humans.

scientific method: a systematic way of gathering and evaluating information by posing specific research questions, designing experiments, making observations and measurements and compiling and interpreting results to answer the questions.

sediment: the deposited material, both organic and inorganic, at the bottom of water bodies.

spawn: to breed and deposit eggs.

stock: a group or population of a fish species that is different from other groups of the same species (i.e. spawns in a different habitat, at a different time).

stunting: reduced growth due to lack of enough food.

thermal stratification: vertical layering of water of different densities that results from water temperature.

toxic: a substance that is poisonous and present in sufficient quantity to cause death or serious injury to an organism.

tributary: (TRIH-bu-tair-ee) stream or river flowing into a larger body of water.

trophic level: any of the feeding levels that energy passes through as it continues through the ecosystem.

turbidity: (tur-BID-i-tee) the condition where sediment and/or other particles are stirred-up or suspended in the water, giving it a muddy or cloudy appearance.

upwelling: a mass of water which has moved to the surface of a lake or the ocean.

watershed: a region or area that is drained by a river system.

weir: (WEER) small dam which may be used for taking spawning fish.

wetlands: areas that contain a lot of soil moisture, can support vegetation that needs wet soil, and has standing water for some part of the year; these areas include swamps, marshes, bogs, coastal areas, and estuaries.

zooplankton: (ZO-PLANGK-ton) tiny or even microscopic and floating or free-swimming animals.

Appendix 3

References on Great Lakes Fisheries Resources

CHARACTERISTICS OF THE GREAT LAKES

Beeton, A. M. and D. C. Chandler. 1966. The St. Lawrence Great Lakes. In Limnology in North America (D. G. Frey, ed.), Univ. of Wisconsin Press, Madison, WI.

Botts, L. and B. Krushelnicki. 1988. The Great Lakes: An Environmental Atlas and Resource Book. Available from: Great Lakes National Program Office, U.S. EPA, 230 S. Dearborn St., Chicago, IL 60604.

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THE LIFE IN THE GREAT LAKES

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Journal of the Fisheries Research Board of Canada (prior to 1978)

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"Well, I would suggest to anybody that's interested, they volunteer and get involved. That's the only way we're going to keep this lake and the rest of them is to get involved. Get out there and do your part."

Steve Lapish
Sport Fisherman and Citizen Activist
Waukegan, IL
from: The Life of the Lakes: The Great Lakes Fishery

"...we share management in the Great Lakes ecosystem...in bringing together all of the public interests...into a common forum where we manage that resource as a single ecosystem so that we can get all our benefits without any of us, in the acquiring of our benefits, interfering with the benefits that others anticipate. That's the biggest challenge that we have."

John Robertson
Michigan Department of Natural Resources
from: The Life of the Lakes: The Great Lakes Fishery

"There is a uniqueness in the management of the Great Lakes. And that uniqueness is founded on the philosophy that two countries, eight states and one province should generally ignore the dotted line down the middle of the lakes and manage on the basis of holistic ecosystem."

Doug Dodge
Ontario Ministry of Natural Resources
from: The Life of the Lakes: The Great Lakes Fishery

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