Potential Fisheries Research Opportunities in the Great Lakes

Richard D. Clark, Jr., James Diana, and Michael Wiley

School of Natural Resources and Environment
University of Michigan
Ann Arbor, Michigan 48109

Abstract – Many, if not most, native fish stocks and habitats in the Great Lakes were damaged or destroyed by the mid-1900s. For the last 50 years, the focus of fisheries research and management has been on rehabilitation. These efforts have greatly improved the condition of the Great Lakes ecosystem, but rehabilitation still has a long way to go in many areas, and work must continue. Other fisheries research needs and funding in the Great Lakes Region have been, and will continue to be, shaped by fisheries management agencies' issues and problems. Native American fishing rights, resource user conflicts, resource protection and sustainability, and the push to manage via landscape-scale watershed or ecosystem approaches are some of the major issues that must be addressed. The leading form of aquaculture in the Great Lakes Basin is rearing fish for stocking in public waters in hatcheries run by state, tribal, and federal governments. Private sector production of fish for food, stock-out, or bait is growing. Problems in both public and private aquaculture are similar, including release of polluting nutrients, spread of diseases, introduction of undesirable exotic species, and alteration of native gene pools. Applied research is a service to management, so to find fisheries research opportunities in the Great Lakes, one must look as much at the current roles and contributions of fisheries management agencies as at specific biological or ecological problems. Many key fisheries science or management institutions have laboratories or offices in Ann Arbor, making collaborations with the University of Michigan (UM) very convenient. We recommend that UM selects specific research initiatives of mutual interest and offers potential partners support and commitments at the upper University-level of administration, including waivers of indirect costs on research grants and office and laboratory space. The benefits of such partnerships include greater ability to attract outside, non-partner funding (perhaps including indirect costs), greater ability to attract world-class scientists to address research problems and teach, and greater ability to offer relevant hands-on instruction to students. We recommend that UM faculty get more involved in the Great Lake Fishery Commission (GLFC) programs. GLFC plays a lead role in coordinating and funding fisheries research needs in the Region. This is the best way to keep appraised of ever changing research needs. We recommend making regional Great Lakes science (not just fisheries) a programmatic research priority. One of UM's unique strengths is the possibility of addressing fisheries research in a multidisciplinary fashion using expertise in socio-economics, conflict resolution, law, landscape ecology, limnology, marine engineering, and other relevant fields. We recommend that UM recognize and build on past success, such as existing Michigan Department of Natural Resources (MDNR) partnerships. One possibility would be to expand MDNR-UM aquatic Geographic Information System (GIS) capabilities, including developing and maintaining a fisheries spatial data library and conducting more spatial analyses with the assembled data. Addressing fisheries management in landscape and ecosystem perspectives using GIS should be a future growth area.

Introduction

The purpose of this paper is to give a brief status of fisheries and aquaculture management in the Great Lakes region and to identify potential research opportunities for the University of Michigan (UM). We will address only applied research.

From a narrow perspective, the study and management of *fisheries* includes assessing and manipulating exploited aquatic animal populations for use by humans. From a broad perspective, it also includes consideration of unexploited aquatic animals, environments and landscapes, socio-economic factors, and intrinsic values. We will attempt to address fisheries in the broader perspective in this paper and will organize our comments in the context of current fisheries management issues. Also, it is the need for future managers to address fisheries in the broader perspective that is the basis for several of our research recommendations.

Aquaculture involves the breeding and rearing of fishes and other aquatic organisms for food, stock-out, or bait. Aquaculture in the Great Lakes Basin has both public and private sectors. We will address aquaculture research needs within these two sectors.

Fisheries Research Opportunities in the Context of Current Management Issues

The Great Lakes ecosystem was altered dramatically and negatively following settlement of the Basin by European peoples. Land use practices negatively impacted fish habitat, pollution killed or contaminated fishes, overharvest depleted desirable populations, and invading exotic species replaced or reduced native species. Several good descriptions of the history of Great Lakes fisheries exist (e. g. Smith 1972; Wells and McLain 1973; Smith and Tibbles 1980; Bailey and Smith 1981; Eshenroder, et al. 1995; GLFC 2000), so we will not go into detail here. The consequence of history has been that ecosystem rehabilitation and recovery problems are a major focus of Great Lakes research today. However, other needs also exist including research upon which to base management decisions that are geared to protect ecosystems from further degradation or to balance competing societal uses of resources.

Native American fisheries issues

One of the major events in Great Lakes fisheries in the last 20 years has been the success of Native American tribes in reasserting their historic treaty fishing rights. The US courts have consistently ruled that tribes retain fishing, hunting, and gathering rights granted them in 19th century treaties. Issues relating to Native American fishing are likely to have significant impacts on future fisheries research needs.

The entire State of Michigan was subject to treaties between the United States of America (USA) and various Native American tribes. The on-line resources of Central Michigan University's Clarke Historical Library give full text versions and background information for most of the treaties in the upper Midwest, USA. The most relevant to this discussion are the Treaty of Washington (1836) and the Treaty of La Pointe (1842) where Native American's currently engage in active fisheries in the Great Lakes. These two treaties cover approximately two thirds of the State of Michigan (Figure 1).

In addition to hunting, fishing, and gathering rights, the tribes were granted certain sovereign powers by the USA, including the right to establish and enforce fishing regulations pertaining to their own members. States cannot regulate tribal fishing, except in extreme circumstances where it is judged necessary to protect the resource.

State and tribal management jurisdictions overlap, creating a situation in which separate management authorities control separate fisheries all competing for the same stocks. Such competing fisheries usually lead to collapse of the stocks unless authorities coordinate management (FAO 1997). As a measure to conserve stocks, states and tribes were forced to negotiate mutually acceptable protocols for allocating and managing fish stocks in treaty ceded territories of the Great Lakes.

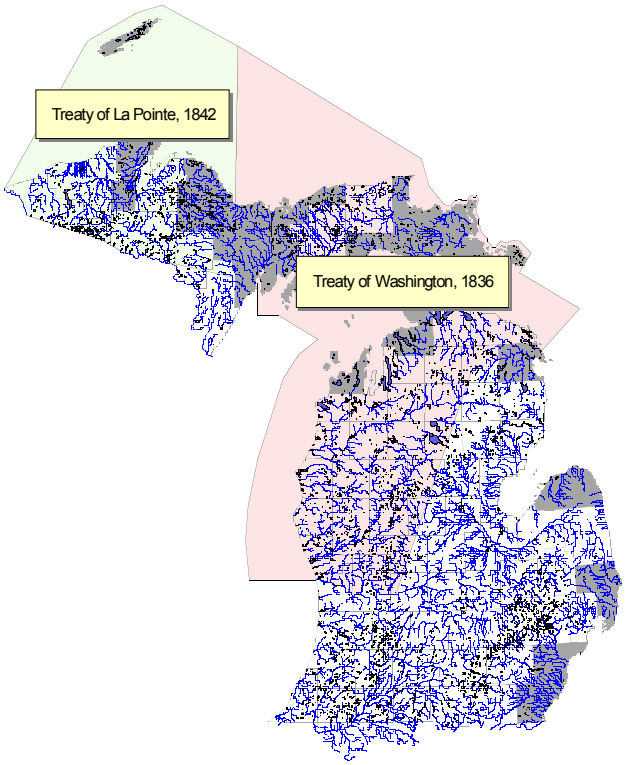

Figure 1. - Treaty-ceded territories in Michigan.

The most recent of these protocols, the 2000 Great Lakes Consent Decree (Enslen 2000), relates to the 1836 ceded territory. In general, the agreement allocates most fish stocks of recreational importance to the State and most stocks of commercial importance to the tribes. Lake trout, which have both recreational and commercial importance, were allocated approximately 50% State and 50% tribes. Lake trout also received special attention in the agreement because of joint interest in restoring natural reproducing populations in lakes Michigan and Huron. In another important element of the agreement, the tribes converted a large number of their fishers from using gill nets to using trap nets. The significance of this conversion relates to the lower by-catch mortality for trap nets. By-catch problems will be discussed further in the next section of this paper. To accomplish the conversion, the State of Michigan bought and retired state-licensed commercial trap net fishing operations in some areas and turned the trap net fishing gear over to tribal-licensed fishers in exchange for their gill nets. The gill nets were then removed from the fishery entirely.

Successful implementation of such agreements requires research in specific areas. The possible opportunities include studies to examine the effects of various fishing methods and regulations, estimate harvest by various fishing groups and gear types, assess fish population status through time, and develop mathematical models to support resource allocation schemes. Socio-economic forces can structure demand and participation in both commercial and recreational fisheries. Studies and models capable of integrating regional socio-economic

development and changing environmental quality with fisheries resource allocation issues are likely to be of interest to both state and tribal resource managers.

Recreational and commercial fishing issues

Recreational fishing is dominated by state- and provincial-licensed fishers. Tribal recreational fishers are few and tribal recreational regulations are similar to state regulations. However, most tribes also have subsistence fisheries that use highly efficient methods of harvest (e.g. spearing fish on spawning grounds or setting gill nets). Subsistence fisheries in the Great Lakes are not closely monitored, though it is generally believed that the current level of fishing effort does not presently threaten resource sustainability. The primary concern regarding the impact of subsistence fishing is for fisheries in smaller, inland bodies of water and is beyond the scope of this paper.

Table 1. – Estimated numbers of fish harvested by recreational fisheries at selected major ports in Michigan waters of the Great Lakes in 1999. Data are from MDNR, Fisheries Division.

	Lake			
Species	Superior	Michigan	Huron	Erie
Lake trout	17,001	31,596	34,280	-
Chinook salmon	1,475	80,109	72,135	-
Coho salmon	6,795	20,015	4,618	-
Rainbow trout	479	27,891	8,795	-
Brown trout	309	20,766	2,092	-
Walleye	-	27,453	43,291	90,542
Yellow perch	5,011	838,899	1,174,512	353,845

Primary species sought by recreational fishers include lake trout, chinook salmon *Oncorhynchus tshawytscha*, coho salmon *O. kisutch*, rainbow trout *O. mykiss*, brown trout *Salmo trutta*, walleye *Stizostedion vitreum vitreum*, and yellow perch *Perca flavescens* (Rakoczy and Svoboda 1997). Numbers of fish harvested by recreational anglers are difficult and expensive to estimate due to the diffuse nature of the fisheries. Most states conduct statistically-based field or mail surveys to make estimates, but methods from state to state are not consistent. Research is needed to develop new, standardized methods for making Great Lakes-wide harvest estimates. Recreational harvest estimates are currently available for Michigan waters (Table 1). These estimates are conducted by MDNR, Fisheries Division at a cost of about 1 million dollars per year.

Many of the most popular recreational species, such as chinook salmon and lake trout, have limited natural reproduction, so their fisheries are dependent on fish reared and stocked by management agencies. For example, Eshenroder et al (1995) reported that about 15 million trout and salmon were stocked in 1994 in Lake Michigan alone. Much research is being done by state and federal agencies to determine best stocking practices, genetic strains, and fishery ecosystem effects of this wide-spread stocking effort. More is needed considering the enormous expense of rearing fish and their potential impacts on the Great Lakes. The numbers of fish stocked in the Great Lakes is biologically difficult to gauge and politically difficult to control. Over stocking has been a problem recently in lakes Michigan (Eshenroder et al 1995), Huron, and Ontario. Management goals now involve determining how to increase natural reproduction so that stocking can be reduced (Eshenroder et al. 1995; GLFC 2000).

Commercial fishing is dominated by tribal-licensed fishers in treaty ceded territories of Michigan, Wisconsin, and Minnesota, but significant state- and provincial-licensed fisheries also exist throughout the Basin.

Primary species sought by commercial fishers vary by state, but include lake whitefish *Coregonus clupeaformis*, bloater *C. hoyi*, lake herring *C. artedi*, rainbow smelt *Osmerus mordax*, channel catfish *Ictalurus punctatus*, walleye, and yellow perch (Table 2). Most of the commercial walleye harvest comes from Canadian waters. No commercial fisheries for walleye exist in US waters, except for some relatively small tribal fisheries in Michigan, Minnesota, and Wisconsin. Tribal-licensed commercial fishers also catch lake trout, chinook salmon, coho salmon, rainbow trout, and brown trout, sometimes as target species and sometimes as by-catch.

Table 2. – Estimated commercial harvest (thousands of pounds) in the Great Lakes in 1999. Data are from Great Lakes Fishery Commission.

	Lake				
Species	Superior	Michigan	Huron	Erie	Ontario
Lake whitefish	2,293	6,669	11,936	1,250	312
Bloater (Chubs)	93	2,073	734	-	-
Lake trout	79	980	522	-	-
Lake herring	1,485	-	38	-	-
Rainbow smelt	31	1,336	15	12,521	-
Channel catfish	-	-	260	337	2
Walleye	-	-	206	9,148	19
Yellow perch	47	177	366	4,186	308

User conflicts – One of the difficult issues confronting Great Lakes fishery managers is dealing with social and biological conflicts between recreational and commercial users. Recreational fisheries directly compete with commercial fisheries for species such as lake trout, walleye, and yellow perch. Commercial fishers often use gears that have problems with by-catch of non-target species. For example, even though fishers of gill nets might be targeting lake whitefish, they most likely will also catch and kill significant numbers of lake trout. Different management authorities across the Basin have treated this conflict differently. Since the 1970s, the State of Michigan has reduced commercial fishing in favor of recreational fishing. Presently, Michigan's state-licensed commercial fishing is restricted to species with low recreational value, and to fishing gears with minimal by-catch problems. However, significant commercial fisheries in other states and Ontario still do exist for some important recreational species, such as walleye and yellow perch, and tribal governments favor commercial fishing over recreational fishing.

Antagonism between commercial and recreational fishers has been a central problem in court cases involving Native American treaty fishing throughout the Basin. A major difference of opinion is over the appropriateness of using gill nets as a commercial fishing gear. Most commercial fishing with gill nets has been banned by the State of Michigan. Gill nets are very

efficient (Table 3) in catching fish and they are easy to use from smaller, less costly boats, but they have significant by-catch problems. This makes them potentially destructive to both recreational and commercial fish populations if not closely controlled by management authorities. Native Americans have used gill nets to fish the Great Lakes for centuries and often see their use as a traditional part of their culture, and so resist restricting their use. Other states and Ontario also still allow commercial gill net fishing.

Table 3. – Average efficiency of gill nets versus recreational fishing gear. Efficiency is compared as catch per unit of effort, catch per typical boat day, and time for 10 boats to harvest 1,000 walleye.

Gear[1]	Catch per effort	Catch per boat per day[5]	Time for 10 boats to harvest 1,000 walleyes
Recreational fishing rod[2]	0.08 fish/ hour	0.3 fish/day	333.3 days (7999 hours)
Gill nets[3]	8.0 fish/lift[4]	80.0 fish/day	1.3 days (31 hours)

[1] Assumes boat fishing with 2 persons per boat for both gears.
[2] Data from Mullett Lake, Cheboygan County, Michigan (Lockwood 2000).
[3] Data is from Laarman (1976). Walleye were not targeted on spawning run. Nets fished June through September.
[4] Net lift for a typical overnight set.
[5] Assumes 2 people in a boat would fish 4-hours per day and fishers using nets would lift 10 nets per day

Another problem in commercial fisheries is by-catch of non-target species as described above for fish, but by-catch problems also include reptiles and aquatic birds, some of which are listed as threatened or endangered species, such as the common loon. The American Fisheries Society has adopted a resolution encouraging state and federal agencies to promote the development, use, and implementation of by-catch reduction devices to conserve fish and wildlife (AFS 2000).

Rehabilitation **–** As mentioned previously, efforts to rehabilitate degraded fish stocks has been a major focus of Great Lakes research, and the greatest interest has been for recreationally or commercially valuable species. Rehabilitation research includes finding ways to reestablish and sustain predator-prey balance, rehabilitate degraded habitats, and return native fish populations to historic abundances and geographic ranges where possible. Rehabilitation has involved rearing and stocking of both native and non-native fishes. Some non-native fishes have become biologically and economically desirable components of the Great Lakes ecosystem.

Fish rehabilitation efforts have succeeded in some areas, but still have a long way to go overall. Notable successes include walleye in Lake Erie and lake trout in Lake Superior. Major restoration efforts continue for lake trout in Lakes Michigan, Huron, and Ontario; walleye in Saginaw Bay; and lake sturgeon Basin-wide. Some historically important species are extinct and cannot be restored (e. g. several species of deepwater ciscos *Coregonus nigripinnus, C. johannae, C. alpenae, and C. zenithicus* – Wells and McLain 1973*)*.

Success of many fish restoration efforts is hampered by the inability to establish natural, self-sustaining reproduction of the native species of concern. In most cases the problem relates to one or more of the following: human-made obstructions, such as dams, block adult fish from riverine spawning grounds; in-lake spawning reefs are physically degraded; reproductive physiology is impaired by pollution or contaminants; survival of eggs, juveniles, or adults is reduced by predation or competition from exotic species; exploitation from fisheries does not allow sufficient numbers of adults to survive and spawn; or inappropriate rearing methods, stocking practices, or genetic strains are being used for reintroduction. Restoration efforts for

lake trout, walleye, and lake sturgeon all suffer from these problems. The many research opportunities in fish restoration involve finding solutions to these and similar problems

Resource protection – Another active area of research is determining ways to help managers protect fisheries from on-going or new environmental threats. This includes work to minimize or eliminate the effects of pollution, climate change, physical habitat alterations, or nuisance exotic species. Research needs include work to: quantify the effects of incremental habitat loss from development; determine ways of exterminating, suppressing, and preventing further invasions of nuisance exotic species (see Jude et al white paper); determine ways to diagnose, cure, and prevent fish epizootics; determine potential impacts of new herbicides or pesticides; quantify the effects of non-point source, landscape-scale pollution and hydrologic alterations.

Resource sustainability – Research is needed to assist managers in sustaining long-term productivity of on-going recreational and commercial fisheries. This includes work to determine: effective means of limiting harvest to safe levels through fishing regulations; ecosystem effects of stocking fish; appropriate and less costly methods to inventory and monitor populations and harvest through time; and quantitative methods for addressing management issues in regional, landscape-scale, and ecosystem perspectives.

Bait harvest – One other type of commercial fishing that has received little attention, and so could be viewed as a possible research opportunity, is the live harvest and resale of small fishes (minnows) and invertebrates for use as bait. There are numerous unmet research needs relating to bait harvest including determining: if harvest is depleting local minnow *Cyprinidae* populations; if harvest is affecting juvenile survival of important recreational species; and if harvest and resale of live bait is a significant vector in the spread of noxious exotic species through angler's bait buckets.

Fishes, amphibians, reptiles, and shellfish not extensively targeted for harvest

Most fisheries management agencies have stewardship responsibility for all aquatic organisms and reptiles, but spend little time or effort on animals not targeted by significant fisheries. Management agencies are forced to address higher priority and politically more important recreational and commercial species with their limited funding. Often neglected animals include most reptiles, amphibians, shellfish, and small fishes. Scientists in university biology or museum curriculums spend more effort on biology and assessment of these animals than the management agencies in charge of them. Unfortunately, these animals suffer the same problems from human-induced environmental impacts as animals being exploited by fishing. Management agencies usually only begin to pay attention to non-exploited species when they reach threatened or endangered status.

Research opportunities for unexploited animals are many, but funding is limited. The basic issues and needs for restoring and protecting these animals is the same as for recreationally and commercially important species. The Conservation and Reinvestment Act (CARA), a bill currently being debated in US Congress, could change the funding situation dramatically. CARA proposes to reinvest $3.1 billion of the federal revenues from off-shore drilling for oil and gas production into state-based wildlife and coastal conservation programs. Part of the money is to be apportioned to state fisheries and wildlife agencies to help fund research and recovery programs for non-game and threatened and endangered species. Passage of this bill could provide a large research opportunity for UM, because state governments are generally not

prepared to utilize such moneys. One way for MDNR to spend their portion would be to expand their partnership programs with state universities like UM.

Ecosystem management

Over the last decade, fisheries resource managers across the globe have begun to take a decidedly broader systems-based view of both research and management issues. For example, the Fish Community Objectives developed for the Great Lakes by the GLFC Lake Committees discuss ecosystem integrity and present as a top goal to restore and maintain the chemical, physical, and biological integrity of the waters of the lake ecosystem (Eshenroder et al 1995; Stewart et al. 1999; Lake Superior Committee 2002). Another example is MDNR's ecosystem management initiative and regional Eco-teams which include fisheries, wildlife, and forestry staff to address management from a broader perspective. And there are numerous other examples.

The UM is well positioned to champion this ecosystem perspective on the Great Lakes in general, and with respect to Great Lakes fisheries in particular. The UM has both strong expertise in biological and physical aquatic sciences, and also world class research capabilities in the socio-economic, engineering, public health, and political (policy) sciences. Interests on campus in integrated studies and the science of complex systems, likewise suggest an opportunity to build a unique and socially relevant research program around the environment of the Great Lakes Basin. The UM could easily take the lead in developing a science-based approach to Great Lakes ecosystem management. The relevance of such a program to issues of fishery science is obvious. Fisheries ultimately are the expression of social and economic interactions with the natural ecosystem. Research leadership in this area would not only enhance the regional reputation of UM, but also, because of the great international visibility of the Great Lakes themselves, could be a flagship program for UM across the world.

Aquaculture

There exists a huge literature on aquaculture. The most recent and relevant information for this paper on the Great Lakes fisheries is on the web sites of the United States Department of Agriculture's North Central Regional Aquaculture Center, the Aquaculture Information Network, and the GLFC's Environmental Assessment Tool for Aquaculture in the Great Lakes (Brister and Kapuscinski 2002). These resources provide information on aquaculture in the region, including the environmental and political issues involved. In particular, the North Central Regional Aquaculture Center provides a series of white papers identifying the research needs for aquaculture production of various species of fish in the Great Lakes Region, and these papers focus mainly on production technology.

Aquaculture has many goals and methods. In this region, aquaculture is mainly directed towards producing fish to stock into natural waters to replenish depleted or non-reproductive fish populations. Such work is done both by governmental and private hatcheries. In addition, aquaculture is important in food production worldwide-indeed about 30% of the fish we currently eat come from aquaculture systems, and this fraction continues to grow as aquaculture expands and wild fisheries continue to collapse (FAO 2000). Methods for aquaculture in this region are predominantly intensive systems, where food is provided with complete artificial diets, water may be exchanged rapidly to remove metabolites and provide oxygen, and chemicals are regularly

added to the water to aid in fish health and disease control. Extensive systems, where waters are fertilized and food for fish produced through natural ecological processes, are rather uncommon in this region except for the culture of baitfish. Indeed, even baitfish culture is as much holding baitfish for future sale as it is controlling and growing baitfish from eggs produced under control. Clearly, the environmental influences of aquaculture, including the release of nutrient rich waters, and introduction of diseases is much more dramatic for intensive aquaculture than it is for less intensive production systems.

Brister and Kapuscinski (2002) reported the existence of approximately 560 aquaculture facilities in the Basin, including those producing food, bait, ornamental, and recreational fishes, as well as, other aquatic organisms. In addition, there has been a growing interest and experimentation in aquaculture by private businesses. Aquaculture in the region includes native fishes like perch, walleye, and some trout, exotic but naturalized species like rainbow trout and Pacific salmon, and exotic species like tilapia and white-striped bass hybrids. In 1998, the commercial value of aquaculture in the Great Lakes region was estimated at $70 million, about 13% of the national value of $978 million (National Agricultural Statistics Survey 1998).

Aquaculture operations of all sorts have been sources of environmental problems and also sometimes blamed incorrectly for other problems. One major problem with fish culture systems is the release of waters back into natural waterways that have high burdens of nutrients, low oxygen levels, and in some cases high levels of drugs or other chemicals. This burden has been shared by public and private operations alike, and has caused the MDNR to start a major rebuilding operation of its hatchery system to have better and less polluting culture systems. Another major problem has been the introduction of diseases, and again this has been shared by public and private systems alike. Problems with Bacterial Kidney Disease (introduced by state hatcheries), and Whirling Disease (possibly introduced by private farms), for example, have resulted in major losses of fishes in wild settings and also the spread of disease from cultured to wild fish. Finally, aquaculture has been a major source of exotic species either intentionally or inadvertently released into natural waters. The government hatchery system is largely in place to produce such exotic species as Pacific salmon for fishery uses. Damages from introduction of exotic species range from those caused by common carp, to recent concerns with other Asian carp and snakehead, and these species have come from both private and public hatcheries.

State, tribal, and federal hatcheries

By far the largest forms of aquaculture in the Great Lakes are fish hatcheries run by state, tribal, and federal governments that rear fish for stocking in public waters. The primary types of fish produced are trout and salmon for use to restore, establish, or maintain fisheries. Most of the species produced in these systems are exotic fish, although native fishes like brook trout and lake trout are also common. One example of such production is the hatchery system for the state of Michigan, and the stocking levels of various species of fish for the year 2001 is a good example of the species mix (Table 4).

In the past, hatchery systems were often managed as factories with a primary objective of maximizing production of fish in weight or numbers. In many cases, not enough emphasis was placed on most efficient methods of production or how well those fish survived to catch in the field. Also, hatcheries have always been plagued with disease and genetics problems that are usually outside the expertise of staff. Hatchery biologists and managers have become increasingly aware of these problems and are seeking answers to them. Recently the MDNR and MSU, with its Colleges of Agriculture and Veterinary Medicine, have teamed up to house an animal disease lab (including state disease specialists) in East Lansing (Gary Whelan, personal communication). In addition, other state, federal, and tribal hatcheries are serviced by the

USFWS, Fish Health Center in La Cross, Wisconsin. Several faculty at UM work on disease issues, particularly in wild populations, and may contribute to the more diagnostic and control of disease orientation at the new center at MSU.

Table 4. – Total pounds by species of fish that were reared and stocked out by MDNR hatcheries in 2001. Data are from MDNR, Fisheries Division.

Species	Pounds
Atlantic salmon	4,986
Brook trout	8,095
Brown trout	93,533
Chinook salmon	33,102
Coho salmon	51,062
Lake trout	121,253
Splake	19,857
Rainbow trout	118,893
Walleye	4,609
Other	9,488

Commercial aquaculture

Production of fish for food – Efforts are underway in the Great Lakes region to raise walleye, yellow perch, and tilapia, while rainbow trout and other salmonids have been reared for many years. All of these production systems for food fish are intensive in nature, giving them the potential to have large environmental effects. Virtually all of the fish produced under intensive systems are high in the food chain and therefore require protein rich feeds. A terrestrial farmer trying to rear wolves or lions as food animals would have similar problems.

Walleye are believed to be a fish with major potential for future aquaculture, because of high demand for walleye and low production through commercial fisheries in the region. Research into rearing walleye for human food markets is underway in Iowa (Summerfelt 2000). Overall research needs for walleye aquaculture are enumerated by Summerfelt (2000).

Some success has been achieved with rearing yellow perch because they are lower on the food chain. However, of more than ten yellow perch farms that became operational in the 1970s, all have closed because they were not economically viable, and many new yellow perch operations that have begun production in the last ten years have already closed for the same reason (Malison 2000). Research needs for yellow perch aquaculture are enumerated by Malison (2000).

Tilapia is grown in nearly every state in the USA. Approximately 2 million pounds of tilapia are produced in the North Central Region of the USA, and virtually all are produced in indoor water recirculating aquaculture systems (Kohler 2000). Tilapia production is considered one of the fastest growing parts of the commercial aquaculture industry in the USA. Research needs for tilapia aquaculture are enumerated by Kohler (2000).

The most common species cultured for food in the North Central USA are salmonids, primarily rainbow trout (Kinnunen 2000). Rainbow trout need large amounts of clean, cold water with high dissolved oxygen content. Therefore, the location of good water sources dictates the location of trout production operations and availability of water resources limits expansion of trout production. Overall research needs for salmonid aquaculture are enumerated by Kinnunen (2000).

Potential new systems for production of cultured species in the Great Lakes region include cage culture in the waters of the Great Lakes and pump ashore systems that use Great

Lakes water for onshore facilities. Some operations have begun in Canada to rear salmonids in pen conditions, and there is likely a market for such fish. Pen culture operations for Atlantic salmon in Norway have been major producers of food fishes and economic return for that country, but these rewards have come at some price in terms of pollution burden, diseases, and the like. Problems like these already exist in the Great Lakes from other sources, and the potential for increasing them does lead one to be cautious. Research into the environmental burdens of new culture systems in the Great Lakes could be a very fruitful area of research as demand for fish continues and supply continues to diminish. Production of fish from aquaculture can even greatly relieve the burden of catch from already overexploited fisheries. One new type of system that could dramatically reduce the pollution burdens and concerns about exotic species is recirculating aquaculture. In such systems, usually done indoors, water is treated and reused rather than discarded. The economic feasibility of such systems is yet to be demonstrated, and such systems could be a focus of future research.

Production of fish for stocking – State fisheries management agencies usually restrict stocking of fish produced in their hatcheries to public waters. Thus, there exists a fairly good market for commercial production of recreational fish for stocking in fee-fishing ponds and other private waters. Species reared successfully for stock-out include walleye (Summerfelt 2000), rainbow trout (Kinnunen 2000), bluegill (Morris and Mischke 2000), largemouth bass (Heidinger 2000), and trout. Research needs are given in detail by those authors.

Production of baitfish – Estimates of aquacultural production of baitfish in the USA are not available, but it is known that significant production occurs in the North Central USA (Gunderson and Tucker 2000). It is currently difficult to separate the wild, commercial harvest of baitfish from aquacultural production. Species produced include white suckers *Catostomus commersoni*, fathead minnows *Pimephales promelas*, and golden shiners *Notemigonus crysoleucas*. Research needs for baitfish aquaculture are enumerated by Gunderson and Tucker (2000).

Regional Fisheries Institutions

Applied research is a service to management, so to find fisheries research opportunities in the Great Lakes, one must look as much at the current roles and contributions of fisheries management agencies as at specific biological or ecological problems. The multi-jurisdictional nature of management authority significantly affects research activity on the Great Lakes. There are multiple federal, state or provincial, and tribal governments with fisheries authority, and within each of those governments a number of agencies (Natural Resources, Environmental Protection, Agriculture, etc.) have authority over matters having direct affect on fisheries. Each of those agencies has an agenda and most directly conduct and/or fund research towards their own ends. In addition, there are a number of organizations whose mission is to provide research service or funding for the management agencies or university scientists.

We will not attempt an exhaustive discussion of management and research agencies in the entire Great Lakes Basin, but will briefly described the agencies with impacts on fisheries research that are relevant to UM's current Great Lakes research initiative. Internet hyperlinks are provided below to each agency's web site for those who seek more information.

Great Lakes Fishery Commission

Any treatment of fisheries research opportunities on the Great Lakes must look closely at the programs and activities of the international Great Lakes Fishery Commission (GLFC). The GLFC was established in 1954 by treaty with Canada and has a narrow but essential fisheries management role – to guide international efforts to suppress the exotic and highly damaging sea lamprey *Petromyzon marinus* (GLFC 2001). However, another of their primary duties is to help coordinate and fund general fisheries research in the Great Lakes Basin, and they are very influential in defining the overall research agenda. They provide a number of forums and services for other management agencies to help coordinate all fisheries related activities in the Basin as much as possible. The GLFC Lake Committees offer management agencies a continuous, structured mechanism to share information, debate issues, and coordinate management and research. The GLFC sponsors scientific symposia and publishes relevant research reports. In addition, GLFC coordinates, funds, or influences much of the fisheries research conducted by universities throughout the Basin. They actively seek research partners to accomplish their mission.

United States Fish and Wildlife Service

The United States Fish and Wildlife Service (USFWS) maintains several Fishery Resources Offices (FRO) throughout the Basin with staff and equipment involved in fisheries research. The research focus of the FROs in the Great Lakes is restoration of lake trout *Salvelinus namaycush*, brook trout *S. fontinalis*, and lake sturgeon *Acipenser fluvescens* populations. USFWS operates several large fish hatcheries producing primarily lake trout for the on-going restoration effort. USFWS operates a fish health center servicing the Upper Midwest with the purpose of helping management agencies in diagnosing and controlling fish diseases. The Health Center also does research on parasitological, viral, and bacteriological fish disease agents.

United States Geological Survey

The United States Geological Survey maintains several fisheries research laboratories in the region, most notably the Great Lakes Science Center (GLSC) in Ann Arbor. GLSC is a dedicated research organization conducting work on fish populations and communities and aquatic habitats. GLSC staff has expertise in fish genetics, mathematical modeling, habitat assessment, and hydroacoustics assessment. GLSC provides their partners a wide variety of data gathering services, including those related to the operation of their five large, open-water research vessels. GLSC research vessels are currently underutilized.

Michigan Department of Natural Resources

Michigan Department of Natural Resources (MDNR), Fisheries Division has general fisheries management authority within Michigan's borders, but cannot regulate tribal fishers in treaty ceded territories. MDNR operates six fisheries research stations, four of which have research vessels operating on the Great Lakes. MDNR research is focused on recreational fisheries management, including fish harvest and population monitoring, studies on the effects of fishing regulations, and investigations of the performance of hatchery fish. MDNR operates six fish hatcheries producing millions of trout and salmon, which are stocked annually in the Great Lakes.

Michigan Sea Grant

Michigan Sea Grant (MSG) is a joint program of Michigan State University (MSU) and UM that is dedicated to the protection and sustainable use of Great Lakes resources. MSG funds fisheries research and provides public education and outreach. MSG research funding

opportunities currently include proposals related to aquatic nuisance species, trophic change, sustainable coastal development, coastal wetlands, and aquatic food web disruption.

Environmental and Limnological Agencies

United States Department of Commerce – National Oceanic and Atmospheric Administration (NOAA), the United States Environmental Protection Agency (USEPA), and Michigan Department of Environmental Quality (MDEQ) are key agencies dealing with fisheries related environmental and limnological issues. Perhaps most relevant to this initiative is the work NOAA conducts through its Great Lakes Environmental Research Laboratory (GLERL). GLERL does work on exotic species, ecosystem dynamics, aquatic contaminants, and physical and climatological topics.

Michigan State University

Michigan State University (MSU) is currently the leading university for fisheries research in the Great Lakes Basin. Its strengths include a College of Agriculture with a Department of Fisheries and Wildlife to address fisheries and aquaculture issues and a College of Veterinary Medicine to address fish health issues. MSU only recently achieved preeminence in Great Lakes fisheries by expanding their faculty in critical research areas through partnership programs. In 1993, MSU attracted and fostered the Partnership for Research and Management (PERM) program, which is a partnership with MDNR, GLFC, and USGS. Through this program, MSU Department of Fisheries and Wildlife has hired 6 faculty members who address Great Lakes fisheries issues, such as stock assessment, habitat assessment, sea lamprey biology, and genetics. Faculty salaries are paid for by the partner agencies. Faculty members develop research programs in their specialty areas and attract outside (non-partner) funding which multiplies the research investments of the partners.

University of Michigan

The University of Michigan (UM) has several faculty members working in traditional fisheries science in the School of Natural Resources and Environment (SNRE). Their strengths include fish behavior, management, physiology, mathematical modeling, river ecology, and watershed analysis. UM also has collaborative arrangements with MDNR for conducting fisheries research, including a PERM agreement similar to MSU's and the Institute for Fisheries Research (IFR – a state funded fisheries research group housed in the UM Museums Annex Building with a full-time staff of about 15 and 8 graduate students). In addition, UM has faculty working in fields that are highly relevant to fisheries, such as socio-economics, conflict resolution, law, landscape ecology, limnology, zoology, and marine engineering. The potential for combining these groups to do multidisciplinary fisheries research may be the most unique strength of UM. There is more to fisheries science than the Great Lakes, and with a few exceptions, UM researchers have focused more on inland lakes and streams or general fisheries biology than on the Great Lakes. UM has really never played a lead role in Great Lakes fisheries research, but had one of the leading groups working in Great Lakes limnology and ecology in the old Great Lakes Research Division.

Recommendations

Provide more University support to potential partnerships

Partnerships must be beneficial for all participants. The historically successful partnerships in fisheries research, such as the IFR and PERM, work on collaborative agreements between the outside group and the UM, not the outside group and SNRE, not the outside group and individual faculty members. The primary reason is that most partnerships hinge on the universities commitment to provide laboratory and office space, make appropriate staff available, and waive indirect costs for partner projects. The authority for many of these decisions exists primarily with the upper-level University administration.

Many key fisheries science or management institutions have laboratories or offices in Ann Arbor, making collaborations with the UM very convenient. We recommend that UM selects specific research initiatives of mutual interest, such as those described below, and offers potential partners University-level support and commitments, such as laboratory space and waiver of indirect costs. The benefits of such partnerships include greater ability to attract outside, non-partner funding (perhaps including indirect costs), greater ability to attract world-class scientists to address research problems and teach, and greater ability to offer relevant hands-on instruction to students.

A good example is how MSU achieved preeminence in Great Lakes fisheries research. MSU's university-level administration made significant commitments. They waived indirect costs for partner-agency grants, made available office and laboratory space, purchased new research equipment, made available clerical and budget management support, and committed to tenure-track status for all the PERM faculty positions.

Get more involved with GLFC

The GLFC is the first and most important new partner to consider with regard to fisheries research. The UM will never play a significant role in Great Lakes fisheries research unless faculty and staff become more involved in GLFC programs and activities. Research needs are dynamic. Any list of research opportunities or priorities we present here could change over night. GLFC provides the best forum for scientists or managers to keep appraised of these changes throughout the Great Lakes Basin. GLFC plays a leading role in coordinating and funding fisheries research. GLFC also greatly influences funding decisions made by other agencies because they regularly assess, identify, and prioritize research needs. We highly recommend increased participation in GLFC programs by UM, either by existing or new faculty.

UM currently has only one faculty member (Ed Rutherford) with any significant involvement with GLFC activities. By contrast, Michigan State University (MSU) has at least 9 faculty members (Bill Taylor, Jim Bence, Kim Scribner, Mary Bremigan, Dan Hayes, Tom Coon, Tracy Dobson, Weiming Li, and Mike Jones) who are deeply involved in GLFC research and programs. These MSU faculty members serve on committees and oversight boards as well as conduct fisheries research. GLFC, through the Partnership for Ecosystem Research and Management (PERM), directly funds salaries of two MSU faculty members (Li and Jones). GLFC specifically mentions in its Strategic Vision (GLFC 2001) that it is seeking to establish additional partnerships to further their agendas.

Make regional Great Lakes science a programmatic research priority

This Great Lakes initiative is about more than just fisheries science. The UM is a world-class research university with a focus that understandably cannot be restricted to regional issues and needs. Nonetheless, as a public university, a far-ranging intellectual agenda is not incompatible with a programmatic commitment to turn university talents and resources towards important regional issues. Indeed it can be argued that there is likely no more efficient way to raise public interest, appreciation, and investment than to be visibly involved in key regional issues. Early recognition that the intellectual environment of the UM at Ann Arbor was an ideal place to address the scientific management of public fisheries resources led to establishment of the USFWS Laboratory on Green Road (now USGS-GLSC). It was a recognition that the UM needed to have a program addressing the Great Lakes that led to hiring David Chandler with a commitment of 5 FTE appointments across departments. The work of Chandler, Ayers, and colleagues eventually developed into UM's Great Lakes Research Division, which by the mid-1980s , included as many as 14 FTEs and a staff of 60-70 students and technicians (i.e. CGLAS) and a university-wide research program focused on Great Lakes science that involved multiple FTEs in many university departments including Geology, AOS, Biology, SNRE, and Public Health. The same recognition that the University was a natural home for applied Great Lakes science led to the establishment of the Michigan (MDOC/MDNR) Institute for Fisheries Research which fostered cross appointments and collaboration between UM faculty at the Museum of Zoology, SNRE, and state government. GLFC, GLSC, the NOAA-GLERL lab are all located in Ann Arbor because at one time the university represented a dynamic regional center of Great Lakes science.

While the universities' program in Great Lakes science is today dramatically reduced in scope, federal and state programs remain in place and are anxious for a renewed partnership. Perhaps surprisingly interest in Great Lakes fisheries science at the university has been maintained at lower but fruitful level (including 3-4 FTEs in SNRE and adjuncts from state and federal labs) and we believe this could be easily strengthened and used as a basis for a broader re-invigoration of UM research in the Great Lakes region. Broadening our own conceptions of what Great Lakes based research involves could help this process. A traditional oceanographic-scale emphasis on deep water research, while often necessary, is being eclipsed by a broader systems level view of resource management (often under the rubric of *Ecosystem Management*) which invites participation from a wider variety of disciplines, regional stakeholders, and research interests. Even with respect to fisheries science, future research opportunities are likely to require a larger degree of engagement with the socio-economic, political, engineering and design sciences, and a regional watershed rather than individual lake-basin orientation. Focusing on the whole house instead just the bathtub is both, essential to doing good resource science, and consistent with the interdisciplinary strengths of a major research university.

Recognize and build on past successes

MDNR, Fisheries Division and UM already have good collaborative relationships that could be further developed with minimal effort – the IFR and PERM programs were mentioned earlier. The IFR is one of the oldest university-state government partnership founded in 1930. It should be noted that the Research Program Manager at the IFR supervises all MDNR fisheries research on the Great Lakes, including 4 field stations with large research vessels and a staff of about 50 people, as well as, a significant aquatic Geographic Information System (GIS) program. Thus, enhanced UM-IFR interactions can bring significant resources to any new Great Lakes initiative.

UM, MDNR, and other fisheries management agencies already have huge investments and nationally recognized expertise in the area of GIS, including spatial data systems

development, maintenance, and analysis. Each agency has its own independent GIS lab with little coordination between agencies and some redundancy in effort. What is needed is more coordination of efforts, more structured collaboration of experts, and more standardization and sharing of data sets. While there are already some GIS data clearing houses or libraries on line, none deals specifically with the huge data sets available in Great Lakes fisheries. UM could make a significant contribution in a short time by developing and maintaining a fisheries spatial data library and developing consistent base funding for infrastructure and management (note: UM and MDNR currently have a significant partnership in GIS, but it is currently based on soft money grants and is not in any way institutionalized). The final, but perhaps most important part of this idea, is for UM faculty and staff to conduct fisheries spatial analyses with the assembled data. We believe many of the management agencies mentioned in this paper would rank such an endeavor as a high priority for partnership funding.

Consider taking advantage of underutilized assets

The USGS, GLSC would probably welcome a partnership with UM. They have significant assets that are currently underutilized, namely 5 large open-lake research vessels. The capabilities of these vessels complement the capabilities of the MDNR vessels. MDNR vessels, which are fully utilized, are good for conducting in-shore fisheries assessments with gill nets or smaller equipment. GLSC vessels are good for conducting off-shore fisheries assessments with heavy equipment such as trawls, hydroacoustics, sonar, or mini-subs. Off-shore fisheries research in the Great Lakes is lacking, partly because it is very expensive and scientists interested in these types of studies are attracted by ocean-going research organizations. One way to take advantage of this opportunity would be to attract a prominent scientist(s) to UM to develop an open-water fisheries program involving the vessels and to provide seed funding for start-up research. State fisheries management agencies would probably rank off-shore research as a high priority for partnership funding. They are currently relying on GLSC for this research, but GLSC is having problems delivering due to staff and funding difficulties.

Invest in specialty areas with long-term potential

Management agencies conduct surveys and research to support their core needs but rely on federal agencies and universities to varying degrees for research in highly specialize areas or for development and testing of new, specialize equipment technologies. Hydroacoustics is a typical example. GLSC has been using hydroacoustics gear for years to estimate abundance of forage fishes in the Great Lakes. GLERL also has scientists knowledgeable with such gear. MDNR has undertaken several research projects to test use of the gear for fish, plant, habitat surveys, and mapping of lakes. With much of this work being centered in Ann Arbor, and given its natural relationship to GIS applications, this is another clear opportunity for UM research.

Treaty fishing management protocols have placed high demands on management agencies for fisheries stock assessment, including estimating present harvest through surveys and projecting future harvest through mathematical modeling. Demands for research work and graduates in these fields are not being met. Currently, there are only two university scientists (Jim Bence at MSU and Patrick Sullivan at Cornell) on the US side of the Basin who are actively doing research and producing students in quantitative fisheries stock assessment. Demand for their research work and employment of their students is greater than they can supply. UM might have to recruit and hire a new faculty member to take advantage of this opportunity, but funding for the position might be available through the partners.

References

AFS. 2000. Policy statement #26: Bycatch reduction devices as a conservation measure. American Fisheries Society, Bethesda, Maryland. 2 p.

Bailey, R. M., and G. R. Smith. 1981. Origin and geography of the fish fauna of the Laurentian Great Lakes basin. Canadian Journal of Fisheries and Aquatic Sciences 38:1539-1561.

Brister, D. J. and A. R. Kapuscinski. 2002. Environmental assessment tool for aquaculture in the Great Lakes Basin Version 1.2.

Eshenroder, R. L., M. E. Holey, T. K. Gorenflo, and R. D. Clark, Jr. 1995. Fish community objectives for Lake Michigan. Great Lakes Fisheries Commission Special Publication 95-3. 56 p.

Enslen, R. A. 2000. Stipulation for entry of consent decree. United States of America, et al., Plaintiff, v. State of Michigan, et al., Defendants. Case No. 2:73 CV 26. United States District Court, Western Michigan, Southern Division. 72 p.

FAO. 1997. *Fisheries Management*. FAO Technical guidelines for responsible fisheries. No. 4. Rome. 82 p.

FAO. 2000. Aquaculture Production. Volume 90/2, Yearbook of Fisheries Statistics, United Nations, Rome, Italy.

GLFC. 2001. Strategic vision of the Great Lakes Fishery Commission for the first decade of the new millennium. 40 p.

Gunderson, J. L., and P. Tucker. 2000. A white paper on the status and needs of baitfish aquaculture in the North Central Region. Currently available on line at the North Central Regional Aquaculture Center. 23 p.

Heidinger, R. C. 2000. A white paper on the status and needs of largemouth bass aquaculture in the North Central Region. Currently available on line at the North Central Regional Aquaculture Center. 11 p.

Kinnunen, R. E. 2000. A white paper on the status and needs of salmonid aquaculture in the North Central Region. Currently available on line at the North Central Regional Aquaculture Center. 19 p.

Kohler, C. C. 2000. A white paper on the status and needs of tilapia aquaculture in the North Central Region. Currently available on line at the North Central Regional Aquaculture Center. 11 p.

Lake Superior Committee. 2002. Fish community objectives for Lake Superior. Great Lakes Fisheries Commission Special Publication. 42 p.

Malison, J. A. 2000. A white paper on the status and needs of yellow perch aquaculture in the North Central Region. Currently available on line at the North Central Regional Aquaculture Center. 16 p.

Morris, J. E., and C. C. Mischke. 2000. A white paper on the status and needs of sunfish aquaculture in the North Central Region. Currently available on line at the North Central Regional Aquaculture Center. 18 p.

National Agricultural Statistics Survey. 1998. Census of Aquaculture. U.S. Department of Agriculture, www.nass.usda.gov,. Washington, D.C.

Rakoczy, G. P., and R. F. Svoboda. 1997. Sportfishing catch and effort form the Michigan waters of lakes Michigan, Huron, Erie, and Superior, April 1, 1994 – March 31, 1995. Michigan Department of Natural Resources, Fisheries Division Technical Report 97-4. 124 p.

Smith, B. R., and J. J. Tibbles. 1980. Sea lamprey (*Petromyzon marinus*) in lakes Huron, Michigan, and Superior: history of invasion and control, 1936-78. Canadian Journal of Fisheries and Aquatic Sciences 37:1780-1801.

Smith, S. H. 1972. Factors of ecologic succession in oligotrophic fish communities of the Laurentian Great Lakes. Journal of the Fisheries Research Board of Canada 29:717-730.

Stewart, T. J., R. E. Lange, S. D. Orsatti, C. P. Schneider, A. Mathers, M. E. Daniels. 1999. Fish Community Objectives for Lake Ontario. Great Lakes Fisheries Commission Special Publication 99-1. 56 p.

Summerfelt, R. C. 2000. A whitepaper on the status and needs of walleye aquaculture in the North Central Region. Currently available on line at the North Central Regional Aquaculture Center. 29 p.

Wells, L., and A. L. McLain. 1973. Lake Michigan man's effect on native fish stocks and other biota. Great Lakes Fishery Commission, Technical Report No. 20. 56 p.