STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES

Number 18 August 25, 1997

Lake Sturgeon Rehabilitation Strategy

Editors:

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and
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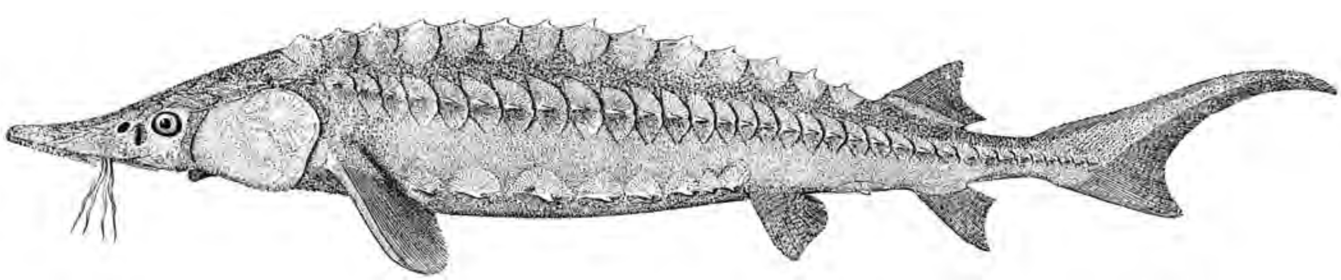

THE LAKE STURGEON.
Acipenser rubicundus, Le S. (p. 661.)
Drawing by H. L. Todd, from No. 10252, U. S. National Museum, collected at Ecorse, Michigan, by J. W. Millner.

From The Fisheries and Fishery Industries of the United States 1884.

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FISHERIES DIVISION
SPECIAL REPORT

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

Fisheries Division Special Report 18
August 25, 1997

LAKE STURGEON REHABILITATION STRATEGY

Lake Sturgeon Committee Report

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Elizabeth M. Hay-Chmielewski
and
Gary E. Whelan

Michigan DNR
Printed under authority of Michigan Department of Natural Resources
Total number of copies printed 75 — Total cost $214.62 — Cost per copy $2.86

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Executive Summary

Lake sturgeon is a potamodromous fish found in many large rivers and lakes in North America. Michigan is in the center of its historic range. Populations in and around Michigan were estimated to number in the hundreds of thousands. Since the mid-nineteenth century, exploitation and habitat degradation have resulted in a substantial decline. Today, these populations are believed to be at 1% of their former size. As a result, Michigan Department of Natural Resources listed lake sturgeon as a state threatened species (Section 36505 (1a), Part 324, Endangered Species Protection, of Act No. 451 of the Public Acts of 1994).

The primary goal of this strategy is to conserve and rehabilitate self-sustaining populations of lake sturgeon to a level that will permit delisting as a threatened species. The sub-goals are to first, conserve and rehabilitate self-sustaining populations, second, where populations have been extirpated, re-establish self-sustaining populations, and lastly when the first two areas are near completion and when opportunities arise establish self-sustaining populations in waters within lake sturgeon's suspected historic range.

This rehabilitation strategy describes the known life history of lake sturgeon including distribution and abundance, reproduction, sub-adult and adult habitat requirements, food preferences, movement patterns, and genetics. It also makes conclusions about what is known and lists area where more information is needed.

Protection and rehabilitation of lake sturgeon habitat is critical. The strategy evaluates present and potential habitat available to lake sturgeon. Criteria were developed to assess rivers and lakes in Michigan for populations and habitat. These criteria and the collective knowledge of the committee members, were used to determine an order for rehabilitation and enhancement work. A set of objectives based on each sub-goal is detailed.

The strategy also describes the difficulties managing lake sturgeon. Rochard et al. (1990) lists three major obstacles to rehabilitating sturgeon worldwide: effects of fishing, physical obstacles for migrating fish, and physical effects on spawning and nursery areas. These problems and others exist in Michigan. Harvest, barriers, sea lamprey control, physical alteration of habitat, water quality, and contaminants are discussed and recommendations to minimize or remove their effects on lake sturgeon suggested.

Finally, a summary of action items is included.

This rehabilitation strategy is the result of several years of meetings and discussions of the Lake Sturgeon Committee, Fisheries Division, Michigan Department of Natural Resources and the comments of many reviewers.

Introduction

Lake sturgeon, *Acipenser fulvescens*, one of 27 sturgeon species world wide, is a potamodromous fish found in many large rivers and lakes of North America. Its range extends from the St. Lawrence River in the east, to Hudson Bay in the north, west to the North Saskatchewan River in Alberta, and south to the Tennessee River in Alabama (Harkness & Dymond 1961, Scott & Crossman 1973). Lake sturgeon belong to an ancient family of fishes that has existed since the Upper Cretaceous period (136 million years ago), the same time that dinosaurs were at the height of their development and the Rocky Mountains began to rise.

Life history traits of lake sturgeon include large size, delayed maturation, low natural mortality of adults, and high fecundity. These traits, which tend to buffer extremes in environmental conditions and consequently have contributed to the success of the species, have now put them at a disadvantage against human-induced mortality and habitat changes. Low natural mortality of adults and delayed maturation produce populations susceptible to over-exploitation, whereas large size and high fecundity make them valuable economically (Beamesderfer & Farr 1994).

Before the 19th century, lake sturgeon populations in and around the State of Michigan had, by historic accounts, a standing crop in the tens of millions of pounds (Tody 1974). Many early references describe lake sturgeon as abundant or plentiful (Kinietz 1965; Slade and Auer 1997). The populations are now estimated to be about 1% of their former abundance (Tody 1974). This decline can be largely attributed to three factors. First, from the time of European settlement until the late 19th century, lake sturgeon were routinely killed as a nuisance species because they became entangled in fishing nets, causing damage. Second, during the late 19th and early 20th centuries, increased harvest, caused by higher market value, devastated the adult population. Third, loss of spawning habitat and nursery areas from construction of dams on spawning rivers, habitat destruction by former logging practices, and poor water quality eliminated most recruitment.

In response to a continuous period (1920s-1990s) of low abundance and loss of recruitment, Michigan Department of Natural Resources (MDNR) listed this species as threatened under the Endangered Species Act (Section 36505 (1a), Part 324, Endangered Species Protection, of Act No. 451 of the Public Acts of 1994). The United States Fish and Wildlife Service (USFWS) considers lake sturgeon to be a species of regional concern. They continue to monitor lake sturgeon and may consider it for elevation to a candidate species, either threatened or endangered, under the federal Endangered Species Act.

Lake sturgeon are now rare in the Great Lakes watershed. They are also a component of the biodiversity of this ecosystem, a biodiversity that MDNR, Fisheries Division, is entrusted to conserve (Biological Diversity Conservation Act of 1992, PA 93).

Goals

The primary goal of this document is to conserve and rehabilitate self-sustaining populations of lake sturgeon to a level that will permit delisting as a threatened species under the Michigan Endangered Species Act (Section 36505 (1a), Part 324, of Act 451 of 1994).

A self-sustaining population is defined as a population that can maintain itself indefinitely without supplemental stocking. To achieve or maintain a self-sustaining population, there must be enough individuals to prevent inbreeding, sufficient spawning, sub-adult and adult habitat, and low human-induced mortality (such as fishing or dam mortality).

This strategy considers individual populations of lake sturgeon as a management unit. Each Great Lake is considered to have a discrete stock consisting of many populations. This assumption is based on preliminary genetics work and will need to be modified further as ongoing studies provide more information.

The following sub-goals are proposed with the intent of achieving coordinated management of each lake sturgeon populations by Fisheries Division. They are listed in descending order of priority, the first goal having the greatest priority. <u>The committee strongly recommends that the first and second sub-goals be near completion before considering the third.</u>

Sub-goal #1. Where populations now exist, conserve or rehabilitate self-sustaining lake sturgeon populations;

Sub-goal #2. Where populations have been extirpated, re-establish self-sustaining lake sturgeon populations when possible to their known former range;

Sub-goal #3. Where opportunities arise re-establish self-sustaining lake sturgeon populations in waters with appropriate habitat and within their suspected historic range.

Life History

Distribution and Abundance

Past distribution and abundance of lake sturgeon in Michigan waters are not well known. It is recognized that the Great Lakes, connecting waters, and many tributaries had significant lake sturgeon populations, probably numbering in the hundreds of thousands to millions (Harkness and Dymond 1961; Houston 1987). The former range of lake sturgeon populations based upon historic accounts (Harkness and Dymond 1961; Houston 1987), and USFWS and MDNR Fisheries Division data has been reconstructed (Table 1). However, this distribution is probably an underestimate as most populations were extirpated before such information was documented. In addition to potamodromous populations, some historic spawning grounds in Great Lakes waters (Table 2) have also been recorded (Organ et al. 1978; MDNR, Fisheries Division files). For a list of rivers and inland lakes which historically or now support spawning populations see Evaluation of Present and Potential Habitat section.

Table 1.– Historic distribution of lake sturgeon in Michigan's inland waters based on recorded catches or biological samples.

Watershed	County
Lake Erie	
Clinton River	Macomb
Huron River	Wayne and Washtenaw
Raisin	Monroe
Lake Huron	
Au Sable River	Iosco and Oscoda
Black Lake	Cheboygan and Presque Isle
Black River	Cheboygan
Burt Lake	Cheboygan
Cheboygan River	Cheboygan
Carp River	Mackinac
Mullett Lake	Cheboygan
Pigeon River	Huron
Saginaw River	Saginaw
Thunder Bay River	Alpena
Tittabawassee River	Saginaw and Midland
Lake Michigan	
Big Manistique Lake	Luce and Mackinac
Boardman River	Grand Traverse
Brevoort Lake	Mackinac
Elk Lake	Antrim
Escanaba River	Delta
Ford River	Delta
Galien River	Berrien
Grand River	Ottawa, Kent, Ionia, Eaton, and Ingham
Indian Lake	Schoolcraft
Kalamazoo River	Allegan
Manistee River	Manistee and Wexford
Manistique River	Schoolcraft and Mackinac

Table 1.–Continued

Watershed	County
Menominee River	Menominee
Millecoquins Lake	Mackinac
Millecoquins River	Mackinac
Muskegon River	Muskegon and Newaygo
Pere Marquette Lake	Mason
St. Joseph River	Berrien
Sturgeon River	Delta
Torch Lake	Antrim
White River	Muskegon and Oceana
Whitefish River	Delta
Lake Superior	
Big Iron River	Ontonagon
Montreal River	Gogebic
Ontonagon River	Ontonagon
Otter Lake	Houghton
Pine River	Marquette
Portage & Torch lakes	Houghton
Sturgeon River	Houghton and Baraga
Tahquamenon River	Chippewa
Waiska River	Chippewa

Table 2.–Historic spawning areas of lake sturgeon in Michigan's Great Lakes waters based on MDNR, Fisheries Division files and Organ et. al. (1978).

Watershed	County
Lake Erie	
Detroit River	Wayne and Monroe
Lake St. Clair	St. Clair, Macomb, & Wayne
St. Clair River	St. Clair
1/2 mi S Stony Point	Monroe
Lake Huron	
Saginaw Bay-Fish Point to Sand Point	Tuscola and Huron
St. Mary's River	Chippewa
Lake Michigan	
1-2 mi North of New Buffalo	Berrien
8 mi North of Pentwater	Mason
Big Sable Point	Mason
Ganges	Allegan
North & South Fox Island	Leelanau
Pier Cove	Allegan
Saugatuck	Allegan
South Haven	Van Buren

Abundance of lake sturgeon has declined dramatically in the last 200 years. Beginning in the mid 1800s, intensive Great Lakes commercial fishing for lake whitefish and lake trout started the decline in lake sturgeon numbers. Commercial fishermen first despised incidentally caught lake sturgeon because both their size and external bony plates tangled and ripped nets. As the fish had little market value, commercial fishermen killed them to prevent net damage (Tody 1974). By 1860, a market developed for smoked lake sturgeon. A few years later it expanded to include caviar and isinglass, a product made from a gelatin derived from the swim bladder. Catch rates and specific targeting for lake sturgeon intensified greatly by 1885 and eventually collapsed the lake sturgeon stock by early this century (Harkness and Dymond 1961).

Because historic population size of lake sturgeon is unknown, estimates were calculated from commercial catch data compiled by the Great Lakes Fishery Commission (Baldwin et al. 1979). From historic literature, it was assumed that an average size fish in the commercial catch was 50 lb. A fishing mortality of 19.2% was estimated from catch curves and is similar to the 20% cited by Threader and Brousseau (1986). Natural mortality was assumed to be 5% based upon literature values for unexploited populations and recruitment 6% (Baker 1980). Other work on long-lived species has shown that when natural mortality and recruitment are similar, they in effect cancel each other out (Rieman and Beamesderfer 1990). This assumption was made for Michigan lake sturgeon populations estimates.

Three approaches were independently used and compared (Table 3). In method one, we extrapolated back from the estimated numbers caught in the commercial catch data. In method two, we calculated populations from best fit exponential equations based on commercial catch data. Both method one and two produce conservative estimates because they consider only fish over 50 lb. In method three, we calculated a Leslie depletion estimate (Ricker 1975), using pounds of fish caught commercially from 1870 to 1917.

Table 3.–Estimated historic population size of lake sturgeon in the Great Lakes. Method one and two are estimated number of lake sturgeon over 50 lb and method three is the estimated number of all lake sturgeon. Estimated standing stocks (using method three), for waters up to 40 ft deep, are 78 lb/acre in Lake Erie, 56 lb/acre in Lake St. Clair, 12 lb/acre in Lake Huron, 35 lb/acre in Lake Michigan, and 27 lb/acre in Lake Superior.

Watershed	Year	Method 1	Method 2	Method 3
Lake Erie	1850		597,000	
	1870			2,573,000
	1885	535,000	580,000	
Lake St. Clair	1850		148,000	
	1870			354,000
	1879	112,000	112,000	
	1885	29,000		
Lake Huron	1840		319,000	
	1870			611,000
	1885	170,000	224,000	

Table 3.–Continued

Watershed	Year	Method 1	Method 2	Method 3
Lake Michigan	1825		2,406,000	
	1870			11,113,000
	1885	145,000		
	1890	977,000	279,000	
Lake Superior	1840		57,000	
	1870			870,000
	1885	23,000	37,000	

Information on the current size of lake sturgeon populations is very sketchy. A few populations have been estimated using tag-recapture methods. However, the most frequent knowledge is based on direct observation. Table 4 presents known sightings and estimates.

Table 4.–Present estimates on size and distribution of lake sturgeon populations in Michigan.

Watershed, river, and reach	Population estimate	Standing stock (lb/acre)	Estimate date	Notes
Lake Erie				
Detroit River	Unknown			Presence based on observation and limited harvest data
Lake St. Clair	Unknown			Presence based on observation and limited harvest data
St. Clair River	Unknown			Presence based on observation and limited harvest data
Lake Huron				
Au Sable R - Otsego Lake	Unknown			Presence based on observation and limited harvest data
Au Sable River - Foote Dam to Mouth	Unknown			Presence based on observation
Carp River	Unknown			Presence based on observation
Cheboygan R - Burt Lake	10-100			Estimate from catch in Burt and Black Lakes
Cheboygan R - Cheboygan Dam to Mouth	Unknown			Presence based on observation
Cheboygan River - Mullet Lake	300-700			Estimate from catch in Mullet Lake and Black Lake
Cheboygan River - Mullet Lake to Cheboygan Dam	Unknown			Presence based on observation

Table 4.–Continued

Watershed, river, and reach	Population estimate	Standing stock (lb/acre)	Estimate date	Notes
Lake Huron continued				
Cheboygan/Black R - Alverno Dam to Cheboygan	Unknown			Presence based on observation
Cheboygan/Black River - Black Lake	1,599	7.2	1980	Adult (>44 in) population estimate (J. Baker 1980)
Saginaw River	Unknown			Presence based on observation and occasional angler catches
Thunder Bay R - Ninth Street Dam to Mouth	Unknown			Presence based on observation
Lake Michigan				
Brevoort Lake and River	Unknown			Presence based on observation
Galien River	Unknown			Presence based on observation
Grand River - Sixth Street Dam to Mouth	Unknown			Presence based on observation
Kalamazoo R - Calkins Bridge Dam to Mouth	Unknown			Presence based on observation
Manistee River - Sharon Rapids to Hodenpyl Impoundment	Unknown			Presence based on observation
Manistee River - Tippy Dam to Mouth	Unknown			Presence based on observation
Manistique R - Manistique Dam to Mouth	Unknown			Presence based on observation
Manistique River - Big Manistique Lake	Unknown			Presence from harvest, stocking rates and observation
Manistique River - Big Manistique Lake to Manistique Dam	Unknown			Presence based on observation
Manistique River - Indian Lake	200	1.1	1981	Adult (> 40 in) population estimate (C. Bassett, USFS)
Menominee River - Grand Rapids Dam to Scott Impoundment	3,201	11.9	1990	Sub-adult (2817) and adult (>42 in - 384) (T. Thuemler, Wisconsin Department of Natural Resources (WDNR))
Menominee River - Menominee Dam-mouth	893	44.2	1991	Sub-adult (465) and adult (> 42 in - 428) (T. Thuemler, WDNR)
Menominee River - White Rapids Dam to Grand Rapids Impoundment	3,156	17.7	1990	Sub-adult (2521) and adult (>42 in - 635) (T. Thuemler, WDNR)
Millecoquins R & Lake	Unknown			Presence based on observation
Muskegon River - Croton Dam to Mouth	Unknown			Presence based on observation

Table 4.–Continued

Watershed, river, and reach	Population estimate	Standing stock (lb/acre)	Estimate date	Notes
Lake Michigan continued				
Pere Marquette R & Lake	Unknown			Presence based on observation
St. Joseph R - Berrien Springs Dam to Mouth	Unknown			Presence based on observation
St. Joseph R - South Bend to Berrien Springs Dam	Unknown			Presence based on observation
Sturgeon River	Unknown			Presence based on observation
White River - Hesperia Dam to Mouth	Unknown			Presence based on observation
Whitefish River	Unknown			Presence based on observation
Lake Superior				
Big Iron River				Presence based on observation
Keweenaw Bay/Portage Lake	1,650 adults		1993	Tagging data (N. Auer, Michigan Technological University)
Monacle Lake	Unknown			Presence based on observation
Ontonagon River	Unknown			Presence based on observation
Otter Lake and River	Unknown			Presence based on observation
Portage & Torch Lakes	Unknown			Presence based on observation
Sturgeon River - Prickett Dam to Mouth	375		1993	Potamodromous population estimate based on direct counts
Tahquamenon River - Lower Falls to Mouth	Unknown			Presence based on observation
Waiska River	Unknown			Presence based on observation

Reproduction

Lake sturgeon spawn from late April through mid-May throughout their range. Spawning takes place when water temperatures are between 55-64°F in Ontario (Harkness & Dymond 1961), between 47-74°F (Kempinger 1988) and 50-64°F in Wisconsin (Slade and Rose 1994), and between 55 and 60°F in the Menominee River (T. Thuemler, Wisconsin Department of Natural Resources (WDNR), personal communication). Females spawn once every 3 to 7 years and males generally spawn every other year (Roussow 1957; Harkness & Dymond 1961), although consecutive year spawning has been documented in 10-20% of Lake Winnebago males (R. Bruch, WDNR, personal communication). This spawning periodicity and the late age of maturation (females 14 to 33 years, males 12 to 22 years) is a critical feature of this species' life history. Fecundity of lake sturgeon depends on size and age. Cuerrier (1949) listed a range of 4,333-5,960 eggs per lb of fish, based on lake sturgeon from 11.5 lb to 112 lb. Harkness & Dymond (1961) suggest that 5,000 eggs per lb of fish is a reasonable estimate for lake sturgeon over 20 lb.

River spawning lake sturgeon use clean rock substrate in areas of a river with local gradients over 5 ft/mi (Auer 1990; T. Thuemler, WDNR, personal communication). LaHaye et al. (1992) working in

Des Praires River, Quebec, found eggs deposited on substrates ranging from fine to medium gravel to boulders, with bottom velocities of 1.3-4.6 ft/s and depths between 9-30 inches. Maximum concentrations of eggs were found in water 17-27 inches deep, with bottom velocities between 2.0-2.8 ft/s, and substrates of coarse gravel. Eggs were not found on fine sand, silt or clay substrates, nor bedrock (either fractured or unfractured). Other researchers in Michigan and Wisconsin have characterized spawning habitat as having mean column velocities over 3 ft/s, depths from 1-10 ft, and clean substrates composed of cobble, boulder and fractured bedrock (Auer 1990; T. Thuemler, WDNR, personal communication).

Lake sturgeon are classified in the litho-pelagophil reproductive guild (Balon 1975) because eggs are broadcast over rocks and gravel and adhere to substrate. Eggs that are not viable generally drift. This was demonstrated in Des Prairies River by LaHaye et al. (1992) who found 79% of drifting eggs were non-viable, whereas only 19.8% of those that had adhered to substrate were non-viable. Eggs hatch in 3-8 days and the yolk sac is absorbed within 9-18 days of hatching (La Haye et al. 1992). Larvae grow to 0.5 inch within two weeks and to 0.8 inch within three weeks; growth slows after this time. LaHaye et al. (1992) found larval drift to begin 18 days after peak spawning and drifting larvae were captured 12 miles downstream within one month of egg deposition.

Sub-adult and Adult Habitat

Sub-adult (lake sturgeon older than 1 year but not yet mature) and adult (mature breeding lake sturgeon) fish confined to river environments use a wide range of habitats, but are often associated with deep runs and pools (>5 ft) and avoid aquatic vegetation (T. Thuemler, WDNR, personal communication). Deep run and pool habitats are particularly important as overwintering areas. Sub-adult fish will use both shallow (<5 ft) and deeper water, whereas adult fish are most often only found in deeper water (T. Thuemler, WDNR, personal communication).

For lake sturgeon confined in lakes, range of habitats used depends upon availability. In shallow lakes such as Lake Winnebago, Wisconsin (maximum depth 21 ft) and Indian Lake, Michigan (maximum depth 18 ft), fish were found throughout the lake at all depths (Priegel & Wirth 1971; Bassett 1982). In lakes with greater variation in depth and substrates such as Black Lake, Michigan (maximum depth 55 ft), adult fish were found primarily between 20-36 ft although they ranged from 10-55 ft (Hay-Chmielewski 1987). Hay-Chmielewski (1987) observed that lake sturgeon used significantly shallower depths in the winter (23.3 $\pm$ 2.6 ft) than in the summer (33.8 $\pm$ 6.9 ft).

Both Bassett (1982) and Hay-Chmielewski (1987) suggested that sloped areas of lake bottom were important for lake sturgeon. Muck substrates are used extensively in all types of lakes examined. These preferences for depth and substrate correlate with most frequently observed foods in lake sturgeon stomachs. Information on Great Lakes habitat use is minimal. Generally these populations are believed to use similar substrates as lake-confined fish to depths of 60 ft (Harkness & Dymond 1961).

Water temperature preferences for lake sturgeon have not been well documented. Harkness and Dymond (1961) reported that fish go into deeper water during summer months, presumably as they seek cooler, more oxygenated water and return to shallow areas in autumn. The only known temperature preference data relates to spawning.

Experiments measuring the relation between temperature and growth showed that lake sturgeon, given enough food, can sustain active growth between 41-72°F, and growth appears to peak around 59°F (Wehrly 1995). However, Diana and Webb (University of Michigan, unpublished data) found higher growth rates at 63.5°F. Growth rates and mortality at 72°F suggest that this is approaching their upper lethal limit (Wehrly 1995). Houston (1987) reports that this species is usually not found above 75°F.

Food

Invertebrates make up the majority of food resources eaten by lake sturgeon. Hay-Chmielewski (1987) reported the main foods (based on biomass consumed) of lake sturgeon inhabiting Black Lake were: in winter - *Orconectes* spp. and *Hexagenia* spp.; and in summer - *Hexagenia* spp., leeches, Chironomids, *Orconectes* spp., *Polycentropus* spp. and nematodes. Mollusks were also seen, although not in large amounts. These data are consistent with observations for Lake Nipigon lake sturgeon (Adamstone & Harkness 1923; Harkness 1923; Harkness & Dymond 1961). Kempinger (1996) found *Chironomus plumosus, Leptodora kindtii*, and *Daphnia* spp. to be the principal food items for young lake sturgeon inhabiting Lake Winnebago, Wisconsin. Bruch (WDNR, personal communication) has found various species of fish including centrarchids, gizzard shad, and mottled sculpins in the stomachs of sub-adult (3-10 years) and adult lake sturgeon from the Winnebago Chain of Lakes, Wisconsin. These samples were taken primarily in the winter months. Over the last 5-7 years gizzard shad have been fairly abundant in the lakes and have made up a large part of the winter diet.

Movement

Movement patterns of lake sturgeon are not well documented. In rivers, tagging studies indicate that individual fish move from 1 to 93 miles (Priegel 1973; Nowak and Jessop 1987; Sandilands 1987; Dumont et al. 1987; T. Thuemler, WDNR, personal communication). One unrestricted population in Lake Superior has documented post-spawning movements of 100-200 miles (N. Auer, MTU, personal communication). Existence of home ranges is not clear. In rivers, lake sturgeon have been documented as passing over dams and waterfalls (Priegel 1973; Sandilands 1987; R. Bruch, WDNR, personal communication), usually downstream, but on occasion, upstream. In some lakes, only random movement patterns with no home range have been noted (Hay-Chmielewski 1987; Larson 1988). Lyons and Kempinger (1992) found a strong homing instinct by fish in the Lake Winnebago system and distinct spawning locations for fish from different parts of this system. Some lake sturgeon in this system appear to stage beginning in the fall, in the lower sections of rivers, before spring spawning. Lyons and Kempinger (1992) also found evidence for a small separate river population of lake sturgeon in the Wolf River. These fish could, but do not appear to, migrate seasonally to the Lake Winnebago system. The Wolf River is also believed to be a nursery area where sub-adult lake sturgeon spend from 1 to 10 years before moving down to Lake Winnebago (R. Bruch, WDNR, personal communication).

Genetics

For rehabilitation it is critical to know the genetic diversity of a species, so that discrete races, sub-populations, or populations are not extirpated or further degraded. Historically, presumed genetic differences have been assessed from a comparison of morphological characteristics. This method has since been supplemented with comparisons of physiological, biochemical, karyotypic, or molecular methods. Detection of genetic divergence among populations often can be accomplished through the analysis of proteins by electrophoresis. Information on degrees of differentiation allows insights into amounts of genetic variation between populations of the same species (Leary and Booke 1990).

Knowledge of these differences is very important for species where rehabilitation of populations is being considered.

Genetic diversity and environmental influences are responsible for physical variation in performance, growth, and other physical traits of a species. Genetic diversity has two components that need to be recognized and incorporated into a management program: between- and within-population elements. Between-population diversity is affected by mutation, migration, and selection processes that can be predicted quantitatively if information is available. Within-population diversity is affected by inbreeding (non-random mating) and genetic drift (population bottlenecks). The net effect of inbreeding can be a lowering of reproductive output or survival to maturity, an increase in physical deformity, or an increase in disease susceptibility. These can then lead to smaller population sizes, which are most susceptible to genetic drift (Kapuscinski and Jacobson 1987). Ultimately, an inbreeding and drift cycle create an “extinction vortex” (Lacy 1991). As a population spirals inward, it can pass a threshold beyond which it is no longer capable of self-sustaining reproduction. This population size is referred to as the minimum viable population (MVP).

A species’ MVP needs to be established empirically, but as a general principle a “500” rule has been established. The “500” suggests that a minimum of 500 breeding animals will meet long-term genetic diversity objectives and negate large inbreeding effects (Reed et al. 1986; Koenig 1988; Meffe and Vrijenhoek 1988; and Lacy 1991). However, it is important to look at a species effective population size when using this rule. Effective population size is the size of an ideal population that would experience genetic drift and inbreeding at the same rate as the real population under consideration (Kapuscinski and Jacobson 1987). Effective population size differs from census size because not all individuals equally contribute their genes to future generations.

Conceptually, an estimation of effective population size accounts for reduced diversity due to breeding structure and population size. Breeding structures that differ from random mating (where each male has an equal chance of mating with any female and vice versa), such as would be found in an inbreeding or other assortative-mating scheme, translate to a portion or a sample of the genetic diversity being transferred from parents to offspring. Alternately, population sizes that are small can cause a reduction of diversity across generations largely as a “sampling” phenomenon (i.e., biased sampling of total diversity each generation). Under these circumstances, the population will lose a certain amount of genetic diversity each generation. The variables that contribute to the difference between effective population and census population size are unequal sex ratios, unequal proportions of young produced by different parents, and fluctuations in population sizes across generations. **It is strongly suggested that lake sturgeon management use *effective population sizes* rather than census size for minimum numbers.**

Elements of genetic diversity cause populations to diverge from one another. Reproductive isolation, either because of geographical, physical, or biological barriers, prevents mixing of genomes. Mutation and random genetic drift lead to populations possessing different proportions of genotypes. The suite of environmental characteristics present in each population's habitat exerts unique selective forces on the population such that it may become locally adapted. There are also relations between degree of genetic divergence and 1) amount of time since populations interbred and 2) extent of historic interbreeding. Where populations have been isolated for long periods of time without inter-migration and gene flow, divergence is expected to be great. Alternately, recent or partial isolation may diffuse any genetic differentiation.

Rehabilitation of lake sturgeon will require use of hatchery-produced fish for re-introduction into former ranges and for supplementation of some populations. To be successful, it is imperative that correct sources of egg and sperm are selected. This can be accomplished through evaluation of genetic differences between possible donor populations and the population that is present. For the success of rehabilitation it is critical that lake sturgeon used for stocking are of a similar genetic origin to any existing lake sturgeon in the waterbody to be stocked. If lake sturgeon already exist in areas identified for rehabilitation, these existing fish should be the first ones considered as a brood source, provided enough mature adults are available and inbreeding is not extensive. If no lake sturgeon are present, insufficient numbers of mature adults are available, or inbreeding has affected the population, then the most closely related brood source population should be used for rehabilitation. Concern for this originates from experiences where genetically and ecologically divergent populations have been mixed and interbred (Allendorf 1991; Krueger and May 1991; Campton 1995). Population mixing can affect donor and recipient populations in two ways. First, the donor component of this new mix competes directly or indirectly with the recipient component for food and space. In addition, other ecological interactions are possible (such as disease transmissions). Second, if interbreeding between the donor and recipient components is permitted, “outbreeding” effects may surface. Outbreeding effects need not always be deleterious or disastrous, but this will depend on how much the populations have diverged. Mechanisms for “outbreeding depression” are described in Templeton (1986).

One study is underway that will provide some of the needed data on genetic variability in lake sturgeon. Drs. Ted Cavendar and Paul Fuerst at the Ohio State University Museum, in conjunction with Ohio Department of Natural Resources, are evaluating all possible populations of lake sturgeon in the Great Lakes by both electrophoretic and DNA analyses. The DNA technique, which uses a combination of blood samples, tissue plugs, and small fin samples, does not require the sacrifice of fish. This study will also examine historic genetic variability of lake sturgeon throughout their range, using preserved museum specimens. Preliminary findings indicate that lake sturgeon samples from Lake Erie, Lake St. Clair, and Lake Winnebago, Wisconsin have genetic differences based on electrophoretic analysis. These data suggest that the lake sturgeon stock in the Great Lakes shows genetic diversity between populations.

Tissue samples will be provided to this study from lake sturgeon collected during fishery surveys, contaminant sampling, and under Fisheries Division collection permits. Until completion of this study and any complementary investigations concerning lake sturgeon genetic structure, caution is strongly urged in transferring fish among watersheds. This approach, albeit cautious and conservative, will keep potential or purported gene pools separate until fish from distant sources can be proven to originate from the same gene pool. Ultimately, this may require the collection of separate brood stock for the watershed that will receive supplemental rehabilitation stocking.

Conclusions

1) Lake sturgeon’s minimum viable population size must be empirically established. This needs to be calculated considering life history: spawning periodicity, sex differentiation, and length of life. It is anticipated this size would provide a population with the ability to bridge periods of adverse environmental conditions. This information is needed for management.

2) A population should exceed 500 breeding adults before recreational harvest is allowed. This threshold level was chosen for three reasons. First, questionable estimates of survival rates of young lake sturgeon and breeding patterns of adult lake sturgeon results in uncertainty about estimates of effective population size. Second, to limit the harvest to those populations that could support it. The committee felt if harvesting was allowed for smaller populations, there would be the potential for harvest to exceed the target because of the difficulty in monitoring such low harvests accurately.

However, it must be recognized that even moderate harvest pressure, using a 50 inch minimum size limit, could negatively affect populations, because these are the mature reproducing fish. Third, having 500 or more adults should give the population more reserve capacity to withstand annual variations in factors such as recruitment success or harvesting rate. The committee recognizes that determination of this threshold level for Great Lakes populations may be difficult.

3) Investigations into population structure of lake sturgeon to identify the patterns of genetic variation (for geography and life-history) are needed. Knowing native population structure will permit better decisions regarding appropriate sources of broodfish for rehabilitation and of fish when transfers are necessary. Genetically suitable sources for supplementation or reintroduction are critical.

4) Not enough is known about the habitats necessary to all life stages of lake sturgeon. One of the difficulties in managing lake sturgeon populations is our incomplete knowledge regarding all necessary habitats for each life stage. This information in needed to assure proper management of the species.

5) The presence of dams on high gradient reaches at the lower end of large rivers blocks access to spawning grounds. Continued blockage of historic lake sturgeon spawning streams remains one of the largest obstacles to rehabilitation of Great Lakes populations.

6) Knowledge of lake sturgeon populations in Michigan waters is inadequate to determine if harvest should be allowed. There has been concern and much discussion regarding the legal harvest of a state-listed threatened species. Under Section 36505(1a), Part 324, Endangered Species Protection of Act No. 451 of P.A. 1994, a person may not take, possess, transport, import, export, process, sell or offer for sale, buy or offer to buy, any state-determined threatened species. However under sub-section 36505(6b), the taking of a threatened species, when it has been determined that its abundance justifies a controlled harvest, is not in violation of the law. This committee believes that each lake sturgeon populations needs to be assessed on a case-by-case basis to determine if harvest should or should not be allowed. Guidelines for assessment are provided in this document.

Information Needs

Lake sturgeon management is hampered by lack of information. To make sound management decisions and begin rehabilitation of populations, more data on lake sturgeon are necessary. The following areas are most critical:

River Assessments - Lack of historic and present data on many of Michigan's watersheds restricts our ability to manage these complex ecosystems. Because rivers are the traditional lake sturgeon spawning areas, river assessments are needed to aid rehabilitation of this species.

Stock Analysis - An analysis of lake sturgeon Great Lakes stocks and their component populations is needed. The genetic composition of these populations should be determined. These data should be used to guide selection of brood stock. Every attempt should be made to assure the genetic integrity of existing populations. Highest priority needs to be given to Lake St. Clair, Black Lake, and Indian Lake.

Harvest - Re-evaluate the 50 inch minimum size limit for recreational harvest. Under the current 50 inch minimum, there is concern that harvest may be disproportionately selecting for females that are just reaching sexual maturity.

Historic Distribution - A comprehensive analysis of records prepared by the first surveyors of the state and identification of fish bones found in excavated Native American middens is needed. These data would enable us to refine estimates of historic range and further define rehabilitation goals.

Identification of Historic and Present Spawning Areas - Study of old records and survey notes to determine all historic lake sturgeon spawning areas is needed. Also present use areas need to be characterized. This basic knowledge will again aid in rehabilitation.

Sub-adult Habitat Requirements - Studies to determine habitat requirements of sub-adults, particularly young-of-the-year, are necessary to assure protection of these areas. Also more data is needed on larval drift.

Stocking Rates - Develop a model of annual mortality or survival of all life stages of lake sturgeon to assist in determine stocking rates. Determine the appropriate size and number of lake sturgeon for stocking.

Development of Fishways - There are few fishways designed to effectively pass lake sturgeon. A process to develop fishways that pass lake sturgeon has recently been formulated with Canadian Department of Fisheries and Oceans, Ontario Ministry of Natural Resources, WDNR, USFWS, and MDNR. This process needs to be supported.

Development of Downstream Passage Facilities - As discussed previously, lake sturgeon are entrained and killed by hydroelectric powerhouses and spillways. To fully carry out fish passage, it is essential that lake sturgeon moving downstream from spawning, rearing, and feeding habitats be protected. This process should be carried out with Federal Energy Regulatory Commission licensing and should be initiated in cooperation with the WDNR and the USFWS.

Hatchery Needs - Develop alternate food sources to decrease the cost of rearing lake sturgeon.

Development of Pond Culture Methods - The ability of Fisheries Division to raise lake sturgeon is limited by space requirements and expense of feeding fish. Development of pond culture methods should produce larger numbers of lake sturgeon at a lower cost. This type of rearing needs to be investigated.

Evaluation of Present and Potential Habitat

Each river watershed and lake (>5,000 acres) in Michigan, including the Michigan waters of the Great Lakes, was evaluated for its suitability to support and sustain a lake sturgeon population. This qualitative analysis was conducted using known habitat needs of lake sturgeon along with collective knowledge of committee members about each potential water. Criteria used are detailed below. After each variable was examined and consideration given to the stated goals of this strategy, a suitability grade was made.

Rivers

In rivers, critical factors for both inland river (populations confined to river reaches because of barriers) and potamodromous populations are: river size as expressed by mean discharge; river gradient; number of barriers needing passage or removal; and availability of high gradient river reaches for spawning. River size has been documented to be important to lake sturgeon populations (Anon. 1987). River gradient is a key variable controlling physical characteristics of a river by providing its kinetic energy. Gradient is directly related to stream power that controls sediment and woody-debris transport, pool-riffle formation, and sinuosity (Knighton 1984). Barriers prevent upstream movement to spawning sites, prevent seasonal movements for feeding and refuge, and bury spawning sites under impoundments. The amount of existing high gradient spawning habitat will directly control success of maintaining or establishing self-sustaining populations. In addition, inland river systems that contain resident lake sturgeon populations were examined for presence of deep run water, a key habitat type in this circumstance (T. Thuemler, WDNR, personal communication).

Thermal regime of a river is also a key consideration both for reproduction and growth. Cold water streams, typified by trout species, generally warm too late in spring for successful lake sturgeon reproduction and do not allow for good growth rates. Cool water streams, between trout and walleye rivers, may or may not have appropriate springtime temperatures for successful lake sturgeon reproduction and provide temperatures for moderate growth rates. These systems have sporadic recruitment of lake sturgeon. Cool-cold water streams have reaches of each type of water temperature and are between the two in productivity. Warm water streams, typified by walleye-smallmouth bass populations, usually have appropriate springtime temperatures for successful lake sturgeon spawning and support the best growth rates.

Parameters were developed to rank Michigan rivers for their suitability to sustain lake sturgeon populations (Table 5). All Michigan rivers draining into the Great Lakes were analyzed for their suitability to maintain self-sustaining lake sturgeon populations (Table 6).

Table 5.–Criteria used to assess rivers for their suitability to sustain lake sturgeon populations.

Criteria	Suitability groups
Population Status	
Documented population	Yes
Probable population	Yes?
Not probable, but possible historic population	No?
No documented or possible population	No
Discharge	
Mean Discharge > 1000 cfs	Large
Mean Discharge 500-999 cfs	Medium
Mean Discharge <500 cfs	Small
Gradient	
Significant Amounts of Gradient > 5 ft/mi	High
Most Gradient between 3-5 ft/mi	Medium
Most Gradient below 3 ft/mi	Low
Barriers	
>3 Barriers	High
1-3 Barriers	Medium
No Barriers	Low
Deep Run Habitat Available	Yes
	No
Spawning Habitat Available	Yes
	No
River Temperature	Warm water
	Cool water
	Cool-Cold water
	Cold water

Table 6.–Candidate Michigan rivers, by watershed, considered for lake sturgeon rehabilitation or enhancement. Pop'n=population; P. High = potentially high.

Watershed	Pop'n status	Discharge	Gradient	Barrier	Deep habitat	Spawn Habitat	Temper-ature	Suitability
Lake Erie								
Detroit	Yes	Large	High	Low	Yes	Yes	Cool	High
St. Clair	Yes	Large	High	Low	Yes	Yes	Cool	High
Raisin	Yes	Small	P. High	High	Yes	Yes	Warm	Med
Belle	No?	Small	Low	Low	No	No	Warm	Low
Clinton	Yes	Small	Low	Med	No	No	Warm	Low
Huron	Yes	Med	P. High	High	Yes	Yes	Warm	Low
Rouge	Yes?	Small	Low	High	No	No	Warm	Low
Stony Ck.	No	Small	Low	Low	No	No?	Warm	Low
Lake Huron								
Au Sable	Yes	Large	Low	High	Yes	Yes	Cool-Cd	High
Carp	Yes	Small	High	Low	No	Yes	Cool-Cd	High
Cheboygan	Yes	Large	High	Med	Yes	Yes	Cool	High
Saginaw	Yes	Large	High	High	Yes	Yes	Warm	High
St. Mary's	Yes	Large	High	Med	Yes	Yes	Cool	High
Thunder Bay	Yes	Large	High	High	Yes	Yes	Cool	High
Ocqueoc	Yes?	Small	Low	Low	Yes	Yes	Cool	Med
Rifle	No?	Small	Med	Low	Yes	Yes	Cool-Cd	Med
Au Gres	No?	Small	L/Med	Low	No	Yes	Cool-Cd	Low
Black	Yes	Small	Low	Med	Yes	No	Warm	Low
Kawkawlin	No?	Small	Low	Low	No	No	Warm	Low
Munuscong	Yes?	Small	Med	Low	No	Yes	Cool	Low
Pigeon	Yes	Small	Low	Low	No	No	Warm	Low
Pine	No?	Small	Low	Low	No	Yes	Cool	Low
Sebewaing	No?	Small	Low	Low	No	Yes	Cool	Low
Willow	No?	Small	Low	Low	No	Yes	Cool	Low
Lake Michigan								
Escanaba	Yes	Med	High	High	Yes	Yes	Cool	High
Grand	Yes	Large	P. High	High	Yes	Yes	Warm	High
Kalamazoo	Yes	Large	P. High	High	Yes	Yes	Warm	High
Manistee	Yes	Large	Med	Med	Yes	Yes	Cool-Cd	High
Manistique	Yes	Large	Med	High	Yes	Yes	Cool	High
Menominee	Yes	Large	High	High	Yes	Yes	Cool	High
Millecoquin	Yes	Small	Med	Med	Yes	Yes	Cool	High
Muskegon	Yes	Large	High	High	Yes	Yes	Cool-Cd	High
St. Joe	Yes	Large	P. High	High	Yes	Yes	Warm	High
Sturgeon	Yes	Small	Med	Low	Yes	Yes	Cool	High
Whitefish	Yes	Med	High	Low	Yes	Yes	Cool	High
Boardman	Yes	Med	P. High	High	Low	Yes	Cool-Cd	Med
Brevoort	Yes	Small	Med	Med	Yes	Yes	Cool	Med
Cedar	Yes?	Small	High	Low	No	Yes	Warm	Med
Ford	Yes	Med	High	Low	Yes	Yes	Cool	Med
P. Marquette	Yes?	Med	Med	Low	Yes	Yes	Cold	Med
White	Yes	Small	Med	Med	No	Yes	Cold	Med
Betsie	No?	Small	L/Med	Med	No	No	Cool-Cd	Low
Big Sable	No?	Small	L/Med	Med	No	No	Cool-Cd	Low
Black	No?	Small	Low	Med	No	No	Cool	Low

Table 6.–Continued

Watershed	Historic status	Discharge	Gradient	Barrier	Deep habitat	Spawn habitat	Temper-ature	Suitability
Boyne	Yes?	Small	High	Med	No	?	Cold	Low
Days	No?	Small	Med	Low	No	Yes	Cool	Low
Elk	Yes	Small	P. High	High	Yes	?	Cool	Low
Jordan	Yes?	Small	Med	Low	No	Fair	Cold	Low
Lincoln	No?	Small	Low	Low	No	No	Cold	Low
Macatawa	No?	Small	Low	Med	No	No	Cool	Low
Pentwater	Yes?	Small	Low	Med	No	No	Cool	Low
Pine	No?	Small	Med?	Low	No	Yes	Cool	Low
Platte	No?	Small	Med	Med	No	No	Cold	Low
Rapid	No?	Small	High	Low	No	Yes	Warm	Low
Lake Superior								
Ontonagon	Yes	Med	High	High	Yes	Yes	Cool	High
Sturgeon	Yes	Small	High	High	Yes	Yes	Cool-Cd	High
Tahquamenon	Yes	Med	Med	Med	Yes	Yes	Cool	High
Au Train	No	Small	Med	Low	Yes	Yes	Cool	Med
Two Hearted	No?	Small	High	Low	Yes	Yes	Cold	Med
Waiska	Yes	Small	Low	Low	Yes	Yes	Cool	Med
Black	No?	Small	High	High	No	No	Cold	Low
Chocolay	No?	Small	Med	Low	No	No	Cold	Low
Falls	No?	Small	High	High	No	Yes	Cold	Low
Big Iron	Yes	Small	High	Med	No	Yes	Cool	Low
Montreal	Yes	Small	High	High	No	Yes	Cool	Low
Presque Isle	No?	Small	High	High	No	Yes	Cool	Low

Rivers that were determined to have a high suitability rating are where rehabilitation and enhancement work should be concentrated. These rivers coincide with Goal #1. Rivers that were determined to have a medium suitability should be considered for rehabilitation and enhancement only after work nears completion on the first group. Rivers that were determined to have a low suitability should not be considered for lake sturgeon rehabilitation or enhancement work.

Lakes

Factors examined for inland lakes were lake size, amount of suitable habitat in waters less than 40 ft deep, and availability of good river habitat for spawning--gradient and temperature (Table 7). Presence of potential shoal habitat that lake sturgeon may use for spawning was noted, but not given much weight due to lack of confirmed spawning on this substrate. Lake size was selected as a habitat factor based upon studies by Hay-Chmielewski (1987) and Lyons and Kempinger (1992). Amount of shallow water habitat was selected because of the importance of this habitat (Hay-Chmielewski 1987) and because a majority of historic Great Lakes commercial catch was in water less than 40 feet deep (Anon. 1888; 1890; 1892; 1894).

Table 7.–Criteria used to assess inland lakes for their potential to sustain lake sturgeon populations.

Criteria	Suitability groups
Lake Size	
Surface Acreage >15000 acres	High
Surface Acreage between 10000-15000 ac	Medium
Surface Acreage <10000 acres	Low
Presence of Shallow Water Habitat	Yes
	No
Spawning Stream	Yes
	No
Population Status	
Documented population	Yes
Probable population	Yes?
Not probable, but possible historic population	No?
No documented or possible population	No

Considering the above parameters, all inland lakes over 5,000 acres and the Michigan waters of four Great Lakes were analyzed for their suitability to maintain self-sustaining lake sturgeon populations (Table 8).

Table 8.–Candidate Michigan lakes considered feasible for lake sturgeon rehabilitation or enhancement.

Lake	County	Rank and lake size (acres)	Shallow water habitat	Spawning stream	Population status	Suitability
Black	Cheboygan & Presque Isle	Med (10,130)	Yes	Yes	Yes	High
Burt	Cheboygan	High (16,700)	Yes	Yes-Success?	Yes	High
Indian	Schoolcraft	Low (8,659)	Yes	Yes	Yes	High
Big Manistique	Luce & Mackinac	Med (10,130)	Yes	No-shoals	Yes	High
Mullett	Cheboygan	High (17,080)	Yes	Yes-Success?	Yes	High
Portage/Torch	Houghton	Med (10,970)	Yes	Yes	Yes	High
St. Clair	many	High	Yes	Yes	Yes	High
Erie	many	High	Yes	Yes	Yes	High
Huron	many	High	Yes	Yes	Yes	High
Michigan	many	High	Yes	Yes	Yes	High
Superior	many	High	Yes	Yes	Yes	High
Charlevoix	Charlevoix	High (17,000)	Yes	No?	Yes-low numbers	Med
Torch	Antrim	High (18,770)	No	Yes	Yes-low numbers	Med
Crystal	Benzie	Low (9,711)	No	No-shoals	Yes?	Low

Table 8.–Continued

Lake	County	Rank and lake size (acres)	Shallow water habitat	Spawning stream	Population status	Suitability
Elk	Antrim	Low (7,930)	No	No?	Yes-low numbers	Low
Fletcher Pd	Montmorency & Alpena	Low (8,970)	Yes	Yes?	No	Low
Gogebic	Ontonagon Gogebic	Med (14,781)	Yes	No-shoals	No	Low
Grand	Presque Isle	Low (6,080)	Yes	No-shoals	No	Low
Higgins	Roscommon & Crawford	Low (9,900)	No	No	No	Low
Houghton	Roscommon	High (19,600)	Yes	No	No	Low
Hubbard	Alcona	Low (9,200)	Yes	No-shoals	No	Low
Long	Presque Isle & Alpena	Low (5,652)	Yes	No-shoals	No	Low
Michigamme Reservoir	Iron	Low (5,220; 7,000)	Yes	Yes	No	Low
S. Leelanau	Leelanau	Low (5,370)	Yes	No?	No?	Low
Walloon	Emmet	Low (5,487)	No	No	No	Low

Lakes that have a high suitability rating are where enhancement work should be directed. These waters coincide with Goal #1. For inland waters these include: Black, Burt, Indian, Big Manistique, Mullett, and Portage/Torch lakes. Great Lakes enhancement will be considered, pending genetic analysis results and inter-jurisdictional partnerships. Two lakes, Charlevoix and Torch need further study to determine if they should become candidates for enhancement. The remaining lakes should not be considered for enhancement or introduction.

Sub-goals and Objectives

Based on analysis of the life history section, the committee believes that the following objectives listed under each sub-goal should be used as guidelines for lake sturgeon rehabilitation.

Sub-goal #1. Where populations now exist, conserve or rehabilitate self-sustaining lake sturgeon populations;

Objectives:

- for existing populations that have less than 100 adult breeding fish, raise populations to that level within 20 years, to maintain genetic integrity within populations,
- develop sub-adult populations over 300 fish, within five years,
- inventory population size and structure every 10 years,
- inventory known and potential spawning habitat,
- identify obstacles that may be inhibiting natural reproduction,
- if a population has 500 or more breeding adults, a harvestable fishery may be considered,
- where a harvest-oriented fishery is present, maintain fishing mortality below 3% for an expanding population and below 6% to maintain lake sturgeon abundance.

Sub-goal #2. Where populations have been extirpated, re-establish self-sustaining lake sturgeon populations when possible to their known former range;

Objectives:

- identify genetically suitable brood stocks,
- inventory known and potential spawning habitat,
- identify obstacles to rehabilitation and sustainability,
- reestablish a self-sustaining population through transfer or hatchery fish,
- inventory population size and structure, every 5 years, to monitor the success of population building and once sustainability is achieved, every 10 years,
- protect population until such a time that it reaches a minimum of 500 breeding adult fish, after which a harvestable fishery may be considered,
- where a harvest-oriented fishery is developed, maintain fishing mortality below 3% for an expanding population and below 6% to maintain lake sturgeon abundance.

Sub-goal #3. Where opportunities arise re-establish self-sustaining lake sturgeon populations in waters with appropriate habitat and within their suspected historic range;

Objectives:

- identify genetically suitable brood stocks,
- inventory known and potential spawning habitat,
- identify obstacles to rehabilitation and sustainability,
- establish a self-sustaining population through transfer or hatchery fish,
- inventory population size and structure every 5 years, to monitor the success of population building and once sustainability is achieved, every 10 years,
- protect population until such a time that it reaches a minimum of 500 breeding adult fish, after which a harvestable fishery may be considered,
- where a harvest-oriented fishery is developed, maintain fishing mortality below 3% for an expanding population and below 6% to maintain lake sturgeon abundance.

Management Issues and Recommendations

Management of lake sturgeon requires long-term commitment and patience. Rehabilitation of lake sturgeon populations will require efforts by many groups and changing the way a river, lake, or species has been viewed. Instead of focusing on one point within a system, the entire ecosystem needs to be incorporated into a rehabilitation strategy, as many factors influence the one point.

Rochard et al. (1990) lists three major obstacles to rehabilitating sturgeon worldwide: effects of fishing, physical obstacles for migrating fish, and physical effects on spawning and nursery areas. These management issues and others exist in Michigan. Each issue is discussed below followed by management recommendations.

Harvest

The life history of lake sturgeon, particularly their late maturation and longevity, make these populations highly vulnerable to exploitation. As of 1977 all commercial fishing for lake sturgeon in United States waters of the Great Lakes was discontinued. There is no state-licensed commercial harvest of lake sturgeon in Michigan's Great Lakes waters, but some tribal harvest occurs. Commercial fisheries operate in Canadian waters of Lakes Superior, Huron, St. Clair, and the St. Lawrence River (N. Auer, MTU, personal communication). The average annual commercial harvest of lake sturgeon in Ontario waters of Lake Superior is 400 lb, Lake Huron 10,270 lb, and Lake Erie and Lake St. Clair 760 lb for the years 1980-1990 (Anon. 1992).

Recommendations:

1. **Maintain existing regulations that allow no commercial harvest of lake sturgeon in waters regulated by the State of Michigan.**

2. **Encourage agencies that permit commercial harvest of lake sturgeon to reduce their harvest quotas in sensitive areas of Great Lake waters under their jurisdiction.**

During commercial and assessment fishing by-catch may result. By-catch is the incidental capture of species that are not targeted. Historically, nearly all lake sturgeon were target fished either with pound nets, set lines, or large-mesh gill nets (14 in stretch mesh). Presently, a source of by-catch is entanglement in gill, trap, and pound nets (including the leads). Wisconsin DNR monitored their commercial fisheries (1984-1987) and found by-catch of 9 lake sturgeon in gill nets over 204 days and 1 lake sturgeon in 629 trap net sets over 75 days (B. Belonger, WDNR, personal communication). In Michigan waters 651 adult lake sturgeon were tagged on spawning runs in the Sturgeon River (Lake Superior watershed). Thirty-four of these fish have been reported caught: 15 in gill nets at 30-90 ft depth, 13 in trap nets set in water 30 ft deep, and 6 by sport anglers (N. Auer, MTU, personal communication). Whitefish trawling has shown a low by-catch of lake sturgeon, 2 fish in 563 tows in 6 years (P. Schneeberger, MDNR, Fisheries Division, personal communication). Lake sturgeon have also been killed by the Ludington Pumped-Storage Project barrier net (four fish from 1989 to 1993) that uses the same size mesh as trap net leads (approximately 14-inch stretch).

Recommendations:

1. **Maintain existing regulations that allows no retention of lake sturgeon by-catch in waters regulated by the State of Michigan.**

2. **Continue mandatory by-catch reporting of lake sturgeon caught in commercial and assessment fishing to increase information on stock size and structure.**

In a review of lake sturgeon sport harvest in Michigan, it became obvious that scientific data and harvest estimates are grossly inadequate to make sound scientific decisions, especially in recent years. Localized hook-and-line lake sturgeon sport fisheries occur in the lower section of the Menominee River and the St. Clair River delta with incidental catch in other areas. Spearing harvest occurs in Manistique, Indian, Black, and Mullet lakes.

This committee believes that each lake sturgeon population needs to be evaluated on a case-by-case basis to assure proper management. The first step in this process is the determination of population size and structure. Those populations that have little information or cannot withstand any exploitation should be protected from harvest. Populations that can withstand harvest pressure could be allowed to have a managed fishery.

The hook-and-line fishery for lake sturgeon on the Menominee River is managed jointly by the states of Michigan and Wisconsin. Limited harvest is justifiable as the population is closely monitored and mandatory catch registration is required. Nevertheless, regulations governing harvest of Menominee River lake sturgeon are under review. Both states have concerns regarding recent harvest rates and a number of alternatives to reduce harvest are being considered (Thuemler 1994). The most feasible option may be closing the harvest season every other year and allowing catch-and-release only fishing in non-harvest years. This regulation change will be considered for implementation in 1999.

The Otsego Lake population was established by stocking hatchery-reared lake sturgeon. The purpose was to monitor growth and survival of hatchery-reared fish in a natural environment and determine problems, if any. This function has served its purpose in this system. Data for continued evaluation of hatchery fish now comes from the Menominee River using brood stock from the same system. Therefore because the introduced Otsego Lake population is no longer needed for study purposes, the population can be harvested until no more lake sturgeon remain.

Mandatory registration of harvested lake sturgeon is critical for the management of lake sturgeon. Biological data collected would provide accurate figures for harvest, sex and maturity ratio calculation, and size and age structure of the population. These figures would be compared with population estimates to decide whether allowable exploitation rates are being exceeded. A mandatory registration system would also provide managers with demographic information profiling anglers who seek to harvest lake sturgeon. Strict enforcement of the registration requirements would discourage poaching of lake sturgeon from waters where harvest is prohibited. Registration stations could include private businesses (tackle shops, etc.) located near a fishery in addition to MDNR offices. A mandatory registration system is already used on the Menominee River.

Recommendations:

1. **Until sufficient data justifies change, restructure state-wide regulations as follows: an open season for hook-and-line sport fishing from July 16 - March 31 in both inland lakes and the Great Lakes, no possession limit (catch-and-release only). The April 1 - July 15 closure gives complete protection during the spawning season. Exceptions: 1) The Menominee River is covered under the Michigan-Wisconsin Boundary Water Regulations that allows possession of one lake sturgeon per season, minimum size limit of 50 inches, from the 1st Saturday in September-November 1. These regulations are regularly reviewed by biologists of the Wisconsin and Michigan DNR, and changes should be made following their recommendations; 2) Otsego Lake, Otsego County, should be maintained as a hook-and-line fishery, allowable harvest of one lake sturgeon per angler per year, and minimum size limit 50 inches as long as lake sturgeon remain**.

2. **Close spearing statewide, until sufficient data justifies change**.

3. **When a population has been determined to contain at least 500 breeding adults and a harvest fishery is desired, fishing mortality should be no greater than 6%.**

4. **Require that all anglers seeking to harvest lake sturgeon (Menominee River and Otsego Lake) complete a hook-and-line lake sturgeon tag application and obtain a locking tag from a designated lake sturgeon tag outlet. Require successful anglers to seal their fish immediately and within 24 hours, register the fish at a designated lake sturgeon registration station for biological data collection. At that time, a second seal shall be affixed to validate the catch. The carcass may be butchered, mounted, or otherwise disposed of only after it is registered and sealed at a registration station. Possession of a harvest seal on recognized lake sturgeon waters not open to harvest should be prohibited. As other areas are opened to harvest, this system should be extended into these areas.**

Effects of illegal harvest on lake sturgeon populations cannot be accurately estimated, but there is potential for substantial harm to small populations that concentrate in rivers during spawning. MDNR law enforcement personnel indicate that poaching has been and is still perceived to be a problem on the St. Clair and Detroit rivers, despite the closed fishing season during the spawning period. The size of these rivers, combined with many public and private access sites and the international boundary, makes effective law enforcement very difficult (L. Morgan, MDNR, personal communication). In contrast, illegal harvest from the Menominee River is perceived to be minimal. There are very few citations issued for lake sturgeon taken out of season and for possession of undersize fish. Some illegal harvest is known in Indian River, Schoolcraft County (B. LeFever, MDNR, personal communication). The Black River, Lake Huron watershed, is the spawning stream of the Black Lake population. The small size and good clarity of this stream make migrating lake sturgeon very vulnerable to poachers. Fortunately during the past decade this river has received a substantial amount of attention from local conservation officers and volunteer 'watch' groups that has reduced poaching.

Mortality of sub-legal fish taken by legal means may also be a limiting factor in some populations. Michigan law governing commercial and sport fishing requires that sub-legal fish be released immediately, dead or alive. To minimize the incidence of illegal harvest, it is imperative that law enforcement on lake sturgeon issues be given a high priority.

Recommendations:

1. **Encourage law division to give high priority to enforcement on lake sturgeon streams and designated fisheries, especially at spawning areas during spawning events.**

2. **Provide local prosecutors and judges with information that will increase their awareness of the scarcity and value of lake sturgeon.**

3. **Publicize lake sturgeon poaching cases in print and electronic media to make potential violators aware of the consequences of such law violations. Maintain the current restitution value of $1500 per fish.**

4. **Encourage voluntary watch groups to assist Law Division in protecting lake sturgeon, especially during spawning season.**

Barriers

Dams, culverts, and lamprey barriers effectively eliminate spawning habitat for lake sturgeon in many river systems. Barriers deny use of spawning habitat by preventing upstream movement and burying high-gradient habitat under impoundments. Most of Michigan's larger rivers are impounded. This includes 90% of Great Lakes tributaries with a mean annual discharge greater than 1000 cfs (n=11), 69% of Great Lakes tributaries with a mean annual discharge between 500-999 cfs (n=13), and 42% of Great Lakes tributaries with a mean annual discharge between 100-499 cfs (n=33). Usually, the first barrier is located on the first high gradient reach inland from the Great Lakes. Loss of potamodromous habitat to impoundments has been significant. The average remaining available un-impounded potamodromous habitat in large rivers averages 26 river miles per river with only 0.9 miles of high gradient water (> 3.0 ft/mi). These direct habitat losses are obstacles to rehabilitation and management of lake sturgeon and need to be addressed through fish passage (both upstream and downstream) and dam removal.

Besides direct loss of habitat, barriers fragment existing habitat. This changes dynamics of river systems causing a loss in river function that can result in loss of habitat for lake sturgeon. It also prevents use of optimal habitats for each life stage. Dams and occasionally culverts prevent transport of bed materials and woody debris necessary for maintaining a system in equilibrium. Loss of gravel and cobble leads to a direct loss in spawning habitat and frequently degradation of the bed to bare bedrock. Loss of woody debris has been documented to reduce energy available for benthos production and reduce the velocity shelters available for white sturgeon (Maser and Sedell 1994).

Successful rehabilitation of lake sturgeon populations requires that upstream fishways be designed and installed at all barrier locations. Currently, there are no installed fishways that were expressly designed to pass lake sturgeon. Adult lake sturgeon have been observed to pass a pool-weir fishway at Otter Lake on the Otter River, Lake Superior drainage, during streaming flow conditions (R. Juetten, MDNR, Fisheries Division, personal communication). This structure has now been changed to a streaming flow system that allows lake sturgeon passage at different flow levels. Sub-adult lake sturgeon have been observed passing vertical slot fishways at South Bend, Indiana, and at the French Paper Dam on the St. Joseph River in Berrien County (J. Dexter, MDNR, Fisheries Division, personal communication). None of the other 22 fishways in Michigan are properly sized or designed to pass lake sturgeon. They were built to pass Pacific salmonids (St. Joseph and Grand river fishways), walleye (Otter Lake fishway), brook trout (Trout Creek of the Ontonagon River), brown trout (Slagle Creek of the Manistee River), and northern pike (Potagannissing River). On the Upper

Fox River in Wisconsin at Eureka, a fishway at a low-head dam, constructed to pass walleye, is extensively used by lake sturgeon. The fish not only migrate through it but prefer to spawn in the fishway (R. Bruch, WDNR, personal communication). In 1992, an interagency group (USFWS, Department of Fisheries and Oceans Canada, WDNR, MDNR, and Ontario Ministry of Natural Resources) was formed to develop lake sturgeon fishways.

Recommendations:

1. **Remove or provide passage over known obstructions to upstream and downstream movements in rivers and within lake systems. In systems where removal or mitigation of barriers is not feasible at this time, use transferred or hatchery lake sturgeon to rehabilitate populations.**

2. **Continue participation in the interagency group developing lake sturgeon fishways.**

3. **Develop fish passage devices and water-intake screens using these protocol:**

    a) **Require Fisheries Division review of qualifications of selected in-house or outside consultants for approval before development of a fish passage device;**

    b) **Conduct evaluations of all potential fish passage devices or water-intake screens. For upstream devices, include a 2-year device positioning analysis that uses telemetry and tagged fish to determine the proper location for the entrance(s). For downstream fish passage or water-intake screens, include computer hydraulic modeling of all potential designs. Provide a report documenting this evaluation to Fisheries Division for approval.**

    c) **Require a detailed description of the fish passage or water-intake screen device selected be submitted to Fisheries Division for approval. This description should include engineering design specifications, biological design specifications, and operation and maintenance procedures. Justification for the location should also be provided.**

    d) **Install a fish passage device or water-intake screen and within one year, design and implement an effectiveness study with Fisheries Division's approval.**

4. **Request lake sturgeon fishways at all Federal Energy Regulatory Commission (FERC) hydroelectric projects on waters targeted for rehabilitation. Request the participation of all affected hydro owners in the development of lake sturgeon fishways.**

Hydroelectric facilities, including both generating and storage reservoir facilities, have direct and indirect effects on lake sturgeon populations. These effects center around changes in daily and seasonal hydrographs of the river and have been recorded in North America and Russia. These include:

1) reduction in Russian sturgeon reproduction because of changes in flow regime as reflected by the annual hydrograph (Zakharyan 1972; Votinov and Kas'yanov 1978; Veshchev and Novikova 1983);

2) blockage of upstream spawning movements reducing reproductive success (Votinov and Kas'yanov 1978; Thuemler 1985; Auer 1996; MDNR, Fisheries division, unpublished data);

3) insufficient flows during spawning reducing reproductive success (Zakharyan 1972; Votinov and Kas'yanov 1978; Auer 1996);

4) stranding of eggs and adults from rapid changes in discharge that significantly increase direct mortality and poaching (Kempinger 1988; Auer 1996);

5) disruption of spawning migrations, cessation of spawning, and atresia of egg follicles from fluctuating flows (Doroshin and Troitskii 1949; Faleeva 1965; Barannikova 1968; Yelizarov 1968; Khoroshko et al. 1974; Dettlaff et al. 1993; Auer 1996);

6) abnormal gonad maturation and eventual re-absorption of eggs from fluctuating winter flows (Khoroshko 1972; Pavlov and Slivka 1972);

7) delays of spawning caused by lower than normal spring water temperatures because of reservoir affects on temperatures or by fluctuating temperatures from reservoir releases (Zakharyan 1972);

8) low summertime flows can reduce available deep run habitat in rivers and reduce the ability of sturgeon to move to preferred habitats (Anon. 1988). Both factors reduce the production of sturgeon in rivers;

9) abnormally lower water velocities that result in egg clumping, leading to asphyxiation of the inner eggs and increased fungal infections that cause significant egg mortalities (Anon. 1988), and abnormally high water velocities resulting in eggs and larvae being swept away to unfavorable habitats; and

10) a reduction in lake sturgeon lipid concentrations during critical energy periods for populations downstream of peaking hydroelectric projects (McKinley et al. 1993).

There are a number of river systems whose annual hydrographs are altered by hydroelectric storage reservoirs. The effect of altered annual hydrographs is not well understood and should be analyzed on a system by system basis. Conversion of peaking hydroelectric projects to run-of-river projects (where instantaneous inflows equal instantaneous outflows) has been shown to increase ripeness of spawning fish, decrease spawning period, increase number of large adults in the spawning run, and decrease the potential for egg and larvae loss from rapidly changing discharges (Auer 1996). These factors increase the potential for natural recruitment.

Recommendations:

1. **Require all hydroelectric facilities to provide run-of-river flows in river reaches containing lake sturgeon.**

2. **Require all hydroelectric facilities to provide enough flow to allow completion of each lake sturgeon life stage in bypassed and natural river channels.**

3. **Require all hydroelectric facilities to provide an appropriate annual water regime for lake sturgeon where the annual hydrograph has been altered by hydroelectric operations.**

Another effect of hydroelectric projects is entrainment and subsequent turbine mortality of lake sturgeon. At Michigan hydroelectric projects, 36 studies showed an average of 462 fish of all species were entrained daily and 29% were killed by turbine passage (G. Whelan, MDNR, personal communication). Lake sturgeon have been documented entrained at White Rapids, Grand Rapids and Park Mill powerhouses (RMC Environmental Services 1991; Scott Worldwide 1992; Normandeau Associates Inc. 1994), and monitored (by radio telemetry) passing through hydroelectric projects on the Menominee River (T. Thuemler, WDNR, personal communication) and through hydro project spillways in other projects in Wisconsin (Priegel 1973; Holzer et al. 1991; Lyons and Kempinger 1992).

Recommendations:

1. **Require hydroelectric facilities to install protective devices to ensure safe passage through project powerhouses on all river systems that will have upstream lake sturgeon rehabilitation.**

2. **Dam spillways should be made lake sturgeon-friendly by removing or altering hard objects such as energy diffusers at spillway bases or providing directed paths to safe downstream passage.**

Sea Lamprey Control

Since the 1940s, attempts have been made to control sea lamprey populations in the Great Lakes. Effects of this species on lake sturgeon are not well documented. Scott and Crossman (1973) reported capture of a large lake sturgeon in the Bay of Quinte, Lake Ontario, in 1969 that carried 15 adult sea lampreys and scars of many others. In 1990, 1992, and 1994, lamprey scars on spawning lake sturgeon in the Sturgeon River, Houghton and Baraga counties, were counted. In 1990, 6 of 135 adults handled carried a noticeable lamprey scar (4.4%); in 1992, 11 of 121 adults (9%); in 1994, 5 of 112 adults (4.5%). No attempt was made to differentiate between types or ages of wounds; most marks were greater than 1 inch in diameter (N. Auer, MTU, personal communication). However, it must be noted that the Sturgeon River is part of the Lake Superior drainage, where the sea lamprey population is considered to be under control. Rates are suspected to be much higher in Lake Huron and its’ tributaries, the one Great Lake whose sea lamprey populations are not yet considered under control (G. Klar, USFWS, personal communication).

Lampreys less than 6 inches were also commonly seen on lake sturgeon toward the end of the Sturgeon River spawning period (N. Auer, MTU, personal communication). Silver lampreys (*Ichthyomyzon unicuspis*), a native species that co-evolved with lake sturgeon, are also known to parasitize lake sturgeon (Scott and Crossman 1973). These lampreys have been seen on lake sturgeon in Michigan (J. Baker, L. Hay-Chmielewski, MDNR, Fisheries Division, personal communication).

Existing controls for sea lamprey consist of barriers, sterile male programs, and chemical treatments. Unfortunately, sea lamprey spawning migrations overlap with lake sturgeon spawning migrations. Only barriers are a problem to rehabilitation and enhancement of lake sturgeon. Sea lamprey barriers, both physical and electric, cause the same problems as discussed previously for other barriers. Chemical controls, usually 3-trifluoromethyl-4-nitrophenol (TFM) can be toxic to lake sturgeon (Johnson and Weisser 1993). However, it has been found that sea lampreys are more sensitive to TFM than lake sturgeon and concentrations of TFM have been determined that are fatal to sea lamprey but not to lake sturgeon. Johnson and Weisser (1993) using Sturgeon River, Baraga County water (pH 7.9-8.0) found that total sea lamprey mortality was between 1.8 and 1.9 mg/l TFM whereas lake sturgeon (2.8-4.7 in) mortality began at TFM concentrations between 2.7-2.8 mg/l. Recent changes in the federal sea lamprey treatment policy, as a result of these studies, have lead to scheduling treatments to avoid spawning migrations and incubation times of lake sturgeon and to limit the concentrations of lampricides (J. Weisser, USFWS, personal communication). Lake sturgeon larval drift period must also be avoided. Continuation of this policy will ensure that chemical treatments will not adversely affect lake sturgeon rehabilitation.

Recommendations:

1. **Encourage and support continuation of sea lamprey river treatment scheduling to avoid lake sturgeon spawning migrations, egg incubation times, larval drift periods, and hatchery stocking times.**

2. **Encourage and support USFWS policy limiting TFM concentrations on rivers containing lake sturgeon.**

3. **Encourage control of sea lampreys through methods other than permanent barriers.**

4. **When no other options are available for control, encourage and participate in development of barriers with fishways that pass lake sturgeon but restrict sea lampreys.**

5. **Strongly encourage bioassay testing on streams to be treated using both water and indigenous fish from that stream.**

Physical Alteration of Habitat

Waters in Michigan have and continue to be influenced by land use and water flow patterns. Michigan’s landscape has been significantly altered by land use. This includes timber harvest, mining, agriculture, and urbanization. Water flow patterns have been altered by additions, removals, and redirection.

Logging has resulted in excessive inputs of fine sediment and sand, removal of large woody debris from river channels, changes in hydrology, and inputs of saw log wastes into river mouth and coastal shoreline reaches (Maser and Sedell 1994). Inputs of fine sediment have buried critical spawning habitat in some reaches. These sediments remain because of the low stream power (combination of low gradient and stable flows) of Michigan’s river systems. The large number of dams on rivers has also disrupted transport of sediments and large woody debris in these systems. Loss of large woody debris has been shown to cause a decrease in available benthic invertebrate habitat in low gradient streams, a decrease in available coarse and fine particulate organic material that results in a reduced benthic community, and a decrease in velocity shelters which results in white sturgeon using additional energy during migrations (Benke and Wallace 1990; Maser and Sedell 1994). Preventing sturgeon from using optimal habitats for each life stage results in poorer growth. For example, the Columbia River white sturgeon populations that have access to the ocean have higher growth rates, lower ages of first maturity, and have recovered at a much higher rate than confined Columbia River populations. It has been postulated that this is a result of superior nutrition (Galbreath 1985; Pacific States Marine Fisheries Commission 1992). Also, loss of woody debris reduces available cover for lake sturgeon moving both upstream and downstream, making them more vulnerable to harassment and direct predation.

Recommendations:

1. **Require a buffer zone following the guidelines listed in Water Quality Management Practices on Forest Land (1994) on mainstem and tributaries targeted for lake sturgeon rehabilitation.**

2. **Activities such as drainage, flood control, and floodplain development, need to require that woody debris be managed, not removed, unless human safety is jeopardized. Also, all activities need to require protection of woody debris transport processes through river systems. It is crucial that woody debris in river systems be allowed to be processed naturally.**

Removal of old growth forests in Michigan led to destabilization of the hydrograph by increasing runoff and reducing baseflows. This was followed by settlement and agricultural development in large areas of the state. Urban development converts large areas of land into impervious surfaces that destabilize annual water discharge patterns. Flow patterns have been changed through losses of infiltration and in-basin water storage (generally by the drainage of wetlands) and by large amounts of stormwater runoff that are generated during rainstorms. As a result, erosion and non-point pollution increase. Agricultural, through tillage of soils increases erosion and sediment to streams and through drainage destabilizes river flows.

Some recovery has resulted as second growth forests have matured. Conversion of our forests from old growth to secondary growth has probably reduced nutrient inputs into river systems of these watersheds. Further, secondary forests have faster growing characteristics that bind up more nutrients than old growth forests (Vitousek and Reiners 1975). Watershed and stream rehabilitation will be necessary to restore former processes and functions and to fully recover the productivity of these habitats.

Recommendations:

1. **Stabilize to the extent possible, discharge patterns in watersheds to assure success of lake sturgeon rehabilitation and enhancement.**

2. **Include prevention of erosion, rehabilitation of eroded areas, and control of non-point source pollution in master land use plans.**

3. **Remove excess channel sediments in affected streams to facilitate rehabilitation of the river ecosystem.**

Besides habitat alteration caused by logging, discharge of saw log wastes has long been suspected of eliminating the use of river mouth and Great Lakes shoreline habitat by lake sturgeon (Anon. 1888). The addition of large amounts of sawdust caused extremely high biological oxygen demand and low dissolved oxygen concentrations in these locations (Saunders 1981). These conditions eliminated most of the benthic community. Low oxygen levels and absence of benthic food organisms forced lake sturgeon to abandon traditional habitats. Many areas have recovered, but some locations still have significant amounts of sawdust stored in sediments.

Recommendations:

1. **Determine areas presently affected by saw log wastes and mitigate to the extent possible.**

Mining has caused localized water quality and quantity problems in some drainages. These problems result from excessive inflows of fine sediment and sand, disturbance of substrate and sediment transport, and inflows of heavy metals. These problems continue in many areas. Rehabilitation of these sites is needed to restore their productivity for lake sturgeon. Besides water quality problems, a few mining operations have diverted water from one drainage to another or are using large volumes for mine processing.

Recommendations:

1. **Examine water diversions to determine effects on lake sturgeon.**

2. **Require proper screening of all mining water intakes to prevent impingement and loss of lake sturgeon.**

Agricultural and urban development can result in increased amounts of water withdrawals from rivers and streams. Of major concern in systems where lake sturgeon spawn is the time when newly hatched lake sturgeon larvae are drifting downstream. In the Sturgeon River, Lake Superior drainage, larvae have been found to drift from the spawning site beginning in June and are seen 27 mi downstream by July 1 (N. Auer, MTU, personal communication). Losses could result through water withdrawals, especially if taken at night when larval drift is most prevalent. For example, the Ludington Pump Storage Project is estimated to annually entrain and kill 1700 lb of lake sturgeon (MDNR, Fisheries Division, unpublished data). Water intakes that entrain larval, sub-adult and adult lake sturgeon need more study because most fish entrained into industrial intakes are killed. In addition, bridge construction and reinforcement and erosion control must be gauged with consideration of larval drift periods.

Recommendations:

1. **Require that industrial intakes in waters that contain lake sturgeon are adequately screened to prevent entrainment.**

2. **Include consideration of the lake sturgeon larval drift period when issuing water use permits for irrigation and industrial purposes.**

3. **Avoid construction activities on rivers targeted for lake sturgeon rehabilitation from April until late July to avoid critical life cycle stages.**

4. Require an equal replacement for lost lake sturgeon habitat on all construction projects.

Water Quality

Industrialization in Michigan has caused water quality problems. Impaired water quality was a significant factor in the decline of lake sturgeon populations, particularly the large inputs of sawdust into river mouths and inshore areas of the Great Lakes (Anon. 1888; Anon. 1890; Anon. 1892; Anon. 1894; Koelz 1925). Many of the effluents put into these systems, in particular wood manufacturing byproducts, have the potential to disrupt the olfactory feeding behavior of lake sturgeon (A. Rossiter, University of Guelph, personal communication). All point sources in watersheds containing lake sturgeon populations should be evaluated on a system basis. It should be noted that great progress in controlling point source pollution has been made in the last two decades.

Recommendations:

1. Encourage and participate in work to control non-point source pollution.

2. Reduce nutrient and sediment loading to the lowest possible levels to keep spawning substrate clean.

3. Monitor effects of water withdrawal, changes in the annual hydrograph from development, and point source discharges as they relate to stream temperature.

Contaminants

In recent years discovery of toxic chemicals in fish tissue has led to concern for long-term human health issues. These substances, both naturally occurring and manufactured, have resulted in public health advisories recommending who should eat certain species of fish, how much should be consumed, and how often. Bottom feeding and long-lived fish species are known to have large amounts of toxic chemicals in their tissues. As lake sturgeon are included in both categories, they are under study for contaminant loading. Nine chemicals are monitored by the Michigan Department of Community Health in establishing fish consumption advisories (Wood 1993). Mercury and polychlorinated biphenyls (PCBs) are the two substances most frequently found above acceptable levels.

Consumption advisories are issued by size ranges of fish species at specific locations. For organic chemicals, such as PCBs, a restrictive consumption advisory is issued if more than 10% of samples from a species in a predetermined length range is above a level of 2 ppm. If 50% or more samples exceed this level, consumption is not recommended. For mercury, a restrictive consumption advisory is issued for sizes of fish that exceed 0.5 ppm concentration. A no-consumption advisory is issued for those lengths above 1.5 ppm concentration (Wood 1993). Mercury that occurs both naturally through erosion and leaching of mercury-containing geological formations and through human activities such as manufacturing processes and disposal of industrial and consumer products is present in Michigan waters. Lake sturgeon sampled from Lake St. Clair and the Detroit River have amounts of mercury in their tissues above recommended levels and are not recommended for consumption (C. Wood, Michigan Department of Environmental Quality, personal communication). All Michigan inland waters are under a special advisory to restrict consumption due to mercury for all species of fish. Individual analyses of lake sturgeon are being completed to better determine the amounts in this species. In Michigan, the few lake sturgeon analyzed to date have shown toxic loading in fish from the Menominee River and Millecoquin Lake (Table 9). In Wisconsin where more fish have been sampled, mercury levels are generally low.

Lake sturgeon from Green Bay (part of Lake Michigan) and the Menominee River from the first dam to the mouth exceed recommended level for PCBs. All other Michigan samples have been below the action level (Table 9). Two rivers and one lake in Wisconsin have restricted consumption; all others sampled are below the action level.

Table 9.–Lake sturgeon contaminant analysis decisions based on Michigan action levels. Reports are from Wisconsin and Michigan Departments of Natural Resources. (Action level for mercury is 0.5 ppm and for PCBs, 2 ppm.)

Waterbody	Number of fish sampled	Mercury	PCBs
Menominee R. at mouth	6	OK	no consumption
Menominee R. upstream	12	restrict	OK
Millecoquin Lake, MI	1	restrict	OK
Black Lake, MI	1	OK	OK
Lake Michigan (southern)	3	OK	restrict
Chippewa River, WI	6	restrict	OK
Fox River, WI	2	OK	OK
Flambeau River, WI	1	OK	OK
Lake. Winnebago, WI	1	OK	OK
Green Bay	1	OK	no consumption
Lake Superior	3	OK	OK
Wisconsin River, WI	22	OK	restrict
Lake Wisconsin, WI	14	not analyzed	restrict
Peshtigo River, WI	5	restrict	no consumption
Yellow Lake, WI	1	OK	OK

Concerns regarding contaminants go beyond human consumption, and one of the issues raised has been the transport of these substances into inland waters by spawning fish migrating from the Great Lakes. It is unlikely that passage of Great Lakes lake sturgeon into historic spawning rivers will cause contaminant concerns. This species suffers very little mortality from spawning stress, is not a forage item because of their size, and returns to the Great Lakes after spawning.

Effects of contaminants on reproduction and growth in lake sturgeon are not well understood. Copper concentrations are considered a potential threat to egg viability in the Kootenai River population of white sturgeon and are suspected to be one factor contributing to poor reproductive success (Duke 1993). High concentrations of PCBs and DDT are suspected as factors causing near absence of reproduction in pallid sturgeon in the Missouri and Mississippi river systems (Raloff 1994). As rehabilitation of lake sturgeon populations requires successful spawning, it would be desirable to make an assessment of factors influencing egg viability.

Recommendations:

1. **Encourage continued reductions or elimination of contaminant discharges.**

2. **Encourage clean up of known contaminated sites as soon as possible**.

3. **Conduct appropriate studies on contaminant effects on egg viability and survival, larval development and growth, and life expectancy and reproductive organ development of adults.**

Summary of Action Items

The committee recommends the Fisheries Division take the following actions:

General:

- Establish by empirical methods, lake sturgeon's minimum viable population size.
- Acquire data on each lake sturgeon population before management decisions are made.
- Require a population exceed 500 breeding adults before recreational harvest is allowed.
- Complete investigations into population structure of lake sturgeon to identify the patterns of genetic variation (for geography and life-history).
- Determine and protect habitats necessary to all lake sturgeon life stages.
- Investigate and pursue removal of dams on high gradient reaches at the lower end of large rivers. Support work on developing fish passage at dams.

Harvest

- Maintain existing regulations that allow no commercial harvest of lake sturgeon in waters regulated by the State of Michigan.
- Encourage agencies that permit commercial harvest of lake sturgeon to reduce their harvest quotas in sensitive areas of Great Lake waters under their jurisdiction.
- Maintain existing regulations that allows no retention of lake sturgeon by-catch in waters regulated by the State of Michigan.
- Continue mandatory by-catch reporting of lake sturgeon caught in commercial and assessment fishing to increase information on stock size and structure.
- Restructure state-wide sport regulations as listed earlier, until sufficient data justifies change.
- Close spearing statewide, until sufficient data justifies change.
- Allow a harvest fishery only when a population has been determined to contain at least 500 breeding adults. Fishing mortality must be no greater than 6%.
- Require mandatory registration of all sport harvested lake sturgeon.
- Encourage law division to give high priority to enforcement on lake sturgeon streams and designated fisheries, especially at spawning areas during spawning events.
- Provide local prosecutors and judges with information that will increase their awareness of the scarcity and value of lake sturgeon.

- Publicize lake sturgeon poaching cases to make potential violators aware of the consequences of such law violations. Maintain the current restitution value of $1500 per fish.

- Encourage voluntary watch groups to assist Law Division in protecting lake sturgeon, especially during spawning season.

Barriers

- Remove or provide passage over known obstructions to upstream and downstream movements in rivers and within lake systems. In systems where removal or mitigation of barriers is not feasible at this time, use transferred or hatchery lake sturgeon to rehabilitate populations.

- Continue participation in the interagency group developing lake sturgeon fishways.

- Develop fish passage devices and water-intake screens using guidelines discussed earlier.

- Request lake sturgeon fishways at all FERC hydroelectric projects on waters targeted for rehabilitation. Request the participation of all affected hydro owners in the development of lake sturgeon fishways.

- Require all hydroelectric facilities to provide run-of-river flows in river reaches containing lake sturgeon.

- Require all hydroelectric facilities to provide enough flow to allow completion of each lake sturgeon life stage in bypassed and natural river channels.

- Require all hydroelectric facilities to provide an appropriate annual water regime for lake sturgeon where the annual hydrograph has been altered by hydroelectric operations.

- Require hydroelectric facilities to install protective devices to ensure safe passage through project powerhouses on all river systems that will have upstream lake sturgeon rehabilitation.

- Dam spillways should be made lake sturgeon-friendly by removing or altering hard objects such as energy diffusers at spillway bases or providing directed paths to safe downstream passage.

Sea Lamprey Control

- Encourage and support continuation of sea lamprey river treatment scheduling to avoid lake sturgeon spawning migrations, egg incubation times, larval drift periods, and hatchery stocking times.

- Encourage and support USFWS policy limiting TFM concentrations on rivers containing lake sturgeon.

- Encourage control of sea lampreys through methods other than permanent barriers.

- Encourage and participate in development of barriers with fishways that pass lake sturgeon but restrict sea lampreys.

- Encourage bioassay testing on streams to be treated using both water and indigenous fish from that stream.

Physical Alteration of Habitat

- Require a buffer zone following the guidelines listed in Water Quality Management Practices on Forest Land (MDNR 1994) on mainstem and tributaries targeted for lake sturgeon rehabilitation.

- Encourage that woody debris be managed, not removed, unless human safety is jeopardized.

- Stabilize to the extent possible, discharge patterns in watersheds to assure success of lake sturgeon rehabilitation and enhancement.

- Include prevention of erosion, rehabilitation of eroded areas, and control of non-point source pollution in plans.

- Remove excess channel sediments in affected streams to facilitate rehabilitation of the river ecosystem.

- Determine areas presently affected by saw log wastes and mitigate to the extent possible.

- Examine water diversions to determine effects on lake sturgeon.

- Require proper screening of all mining water intakes to prevent impingement and loss of lake sturgeon.

- Require that industrial intakes in waters that contain lake sturgeon are adequately screened to prevent entrainment.

- Include consideration of the lake sturgeon larval drift period when issuing water use permits for irrigation and industrial purposes.

- Avoid construction activities on rivers targeted for lake sturgeon rehabilitation from April until late July to avoid critical life cycle stages.

- Require an equal replacement for lost lake sturgeon habitat on all construction projects.

Water Quality

- Encourage and participate in work to control non-point source pollution.

- Reduce nutrient and sediment loading to the lowest possible levels to keep spawning substrate clean.

- Monitor effects of water withdrawal, changes in the annual hydrograph from development, and point source discharges as they relate to stream temperature.

Contaminants

- Encourage continued reductions or elimination of contaminant discharges.

- Encourage clean up of known contaminated sites as soon as possible.

- Conduct appropriate studies on contaminant effects on egg viability and survival, larval development and growth, and life expectancy and reproductive organ development of adults.

Acknowledgments

The committee thanks Roger Lockwood, James Breck, and James Schneider of the Institute for Fisheries Research, Fisheries Division, for statistical help and philosophical discussions. We thank Ed Baker, Marquette Fisheries Research, Fisheries Division, for discussions, information, and advice. We thank Mason Shouder, retired fisheries biologist, for his contributions early in the development of this document. We thank the United States Fish and Wildlife Service in East Lansing and Tom Thuemler, Wisconsin Department of Natural Resources for their assistance and insights. The discerning comments of many reviewers, especially Rick Clark and Kelley Smith, were appreciated. We thank Kathy Champagne for her invaluable word processing skills.

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