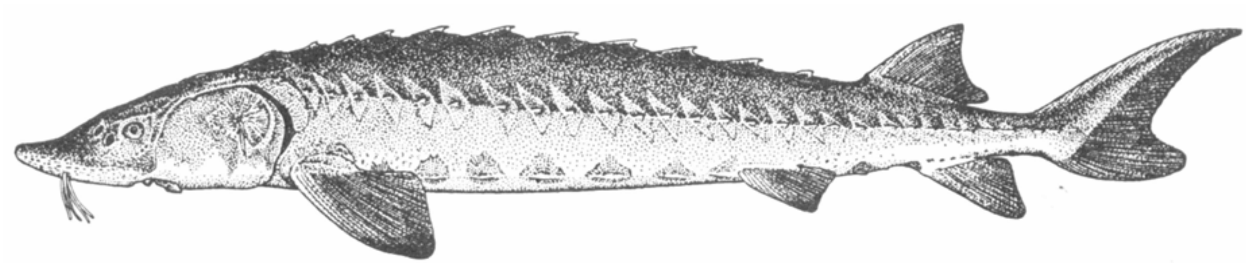


Petition to List U.S. Populations of Lake Sturgeon (*Acipenser fulvescens*) as Endangered or Threatened under the Endangered Species Act

May 14, 2018

NOTICE OF PETITION

Submitted to U.S. Fish and Wildlife Service on May 14, 2018:
Gary Frazer, USFWS Assistant Director, Gary_Frazer@fws.gov
Charles Traxler, Assistant Regional Director, Region 3, Charles_Traxler@fws.gov
Georgia Parham, Endangered Species, Region 3, Georgia_Parham@fws.gov
Mike Oetker, Deputy Regional Director, Region 4, Mike_Oetker@fws.gov
Allan Brown, Assistant Regional Director, Region 4, Allan_Brown@fws.gov
Wendi Weber, Regional Director, Region 5, Wendi_Weber@fws.gov
Deborah Rocque, Deputy Regional Director, Region 5, Deborah_Rocque@fws.gov
Noreen Walsh, Regional Director, Region 6, Noreen_Walsh@fws.gov
Matt Hogan, Deputy Regional Director, Region 6, Matt_Hogan@fws.gov

Petitioner Center for Biological Diversity formally requests that the U.S. Fish and Wildlife Service ("USFWS") list the lake sturgeon (*Acipenser fulvescens*) in the United States as a threatened species under the federal Endangered Species Act ("ESA"), 16 U.S.C. §§1531-1544. Alternatively, the Center requests that the USFWS define and list distinct population segments of lake sturgeon in the U.S. as threatened or endangered.

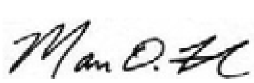
Lake sturgeon populations in Minnesota, Lake Superior, Missouri River, Ohio River, Arkansas-White River and lower Mississippi River may warrant endangered status. Lake sturgeon populations in Lake Michigan and the upper Mississippi River basin may warrant threatened status. Lake sturgeon in the central and eastern Great Lakes (Lake Huron, Lake Erie, Lake Ontario and the St. Lawrence River basin) seem to be part of a larger population that is more widespread. Lake sturgeon introduced into Alabama and Georgia derive solely from out of basin stocks. Eight Canadian populations of lake sturgeon are already listed as endangered, threatened or "special concern" in Canada.

The Center requests that critical habitat for all listed U.S. populations of the lake sturgeon be designated concurrent with listing.

This petition is filed under §553(e) of the Administrative Procedure Act ("APA" - 5 U.S.C. §§ 551-559), §1533(b)(3) of the ESA, and 50 C.F.R. §424.14(b). This petition sets in motion a specific administrative process as defined by §1533(b)(3) and 50 C.F.R. §424.14(b), placing mandatory response requirements on the USFWS. Because *Acipenser fulvescens* is exclusively a fresh water fish, the USFWS has jurisdiction over this petition.

The Center for Biological Diversity is a nonprofit environmental organization dedicated to the protection of native species and their habitats. The Center submits this petition on its own behalf and on behalf of its members and staff with an interest in protecting the lake sturgeon and its habitat.

Contact: Marc Fink



209 E. 7th Street, Duluth, MN 55805
mfink@biologicaldiversity.org
(218) 464-0539

EXECUTIVE SUMMARY

The lake sturgeon (*Acipenser fulvescens*) is a large, long-lived, freshwater fish species that historically inhabited rivers and lakes throughout three major North American watersheds—Hudson Bay, the Great Lakes basin, and the Mississippi River drainage. Sturgeons are an ancient and successful lineage of fishes, having survived relatively unchanged for 200 million years.

Lake sturgeon can attain ages up to 100 years, grow to over 8 feet long and weigh up to 300 pounds. They have no scales but are covered by five rows of bony scutes on the back and sides. Lake sturgeon are iteroparous, characterized by multiple reproductive cycles over the course of their lifetime. Preferred habitats are large shallow lakes, rivers and near-shore areas. Lake sturgeon feed by using their protruding mouths to suction up bottom dwelling organisms such as crayfish and other crustaceans as well as insect larvae.

Sturgeons in general are highly vulnerable to habitat alteration and over-fishing because of their specialized habitat requirements, the long time it takes them to reach breeding maturity, and their episodic reproductive success. Lake sturgeon have a low reproductive rate and may not begin to spawn until they are 15-25 years old. Mature males spawn on average every other year and females spawn on average every three to four years.

The history of sturgeon fisheries throughout the world has been one of overexploitation followed by severe population reduction. Due to excessive harvests in the 1800s, lake sturgeon quickly transitioned from a “nuisance species” of incredibly high abundance to a highly desired commercial species to a severely depleted species. Concurrent with overfishing were anthropogenic habitat alterations that have done irreparable damage to lake sturgeon habitat, including dam construction which blocked access to spawning and rearing habitat, dramatic changes to water quality due to water pollution, and ecosystem changes from water diversions, logging, conversion to agriculture, and river channelization.

Lake sturgeon in the United States warrant listing as “threatened” under the federal Endangered Species Act. Lake sturgeon populations in Minnesota, Lake Superior, Missouri River, Ohio River, Arkansas-White River and lower Mississippi River may qualify as “endangered.” Lake sturgeon populations in Lake Michigan and the upper Mississippi River basin may qualify as “threatened.” Lake sturgeon populations in the central and eastern Great Lakes (Lake Huron, Lake Erie, Lake Ontario and the St. Lawrence River basin) are less imperiled. Lake sturgeon introduced into Alabama and Georgia derive solely from out of basin stocks. Eight Canadian populations of lake sturgeon are already listed as endangered, threatened or “special concern” in Canada.

The historical abundance of lake sturgeon in the Great Lakes alone was impressive: it is estimated that more than 15 million sturgeon inhabited the Great Lakes in the late 1800s. Lake sturgeon abundance is now reduced to less than one percent of historic levels in their native range, with most of the remaining spawning populations showing little or only limited signs of natural recovery. Lake sturgeon have been extirpated from most of their former rivers and tributaries in the Mississippi River basin, and are extirpated or depleted in many of the tributaries to the Great Lakes.

In Northwestern Minnesota, formerly abundant lake sturgeon populations in the Red River and many of its tributaries have been largely extirpated. There are still relatively large numbers of lake sturgeon in the Lake of the Woods-Rainy River system and unknown numbers in Rainy Lake. Stocking of lake sturgeon is occurring in the Red River in Minnesota and in the Assiniboine River in Canada, but reproducing populations have not yet been established.

In Lake Michigan, lake sturgeon have been extirpated from 14 of 27 former spawning tributaries, and are at dangerously low population numbers in 10 additional tributaries. Only about 3,000 adult lake sturgeon are believed to remain in Lake Michigan, with approximately 1,400 spawning age adults in lower Green Bay. In western Lake Michigan, former spawning populations have been extirpated from 12 of 20 tributaries. In an additional 5 western Lake Michigan tributaries lake sturgeon persist only as very small remnant runs, with no more than 25-50 annual spawners, well below minimum population viability. There are small spawning populations in the Peshtigo River and the Menominee River. The only significant lake sturgeon population left in the Lake Michigan area is in Lake Winnebago, with about 20,000 adult spawners in the entire system. In eastern Lake Michigan, former lake sturgeon spawning populations have been extirpated from 2 of 7 tributaries as well as from Wolf Lake. In an additional 5 eastern Lake Michigan tributaries lake sturgeon persist only as small remnant runs, with no more than 20-100 annual spawners. There are no remaining large populations of lake sturgeon in eastern Lake Michigan.

In Lake Superior, lake sturgeon have been extirpated from 7 of 9 former spawning tributaries on the U.S. side. Small, self-sustaining populations now occur only in the Sturgeon River and its tributary Otter River, and the Bad River and its tributary White River. Lake sturgeon have since been restocked in the St. Louis and Ontonagon rivers but there has been limited evidence of spawning and the population sizes are extremely small or unknown. On the Canadian side of Lake Superior, former lake sturgeon spawning populations have been extirpated from 7 of 15 tributaries. Remaining populations in 8 Canadian tributaries are all small, with unknown population sizes.

Lake sturgeon populations in Lake Huron, Lake Erie, Lake Ontario and the St. Lawrence River appear to comprise a larger population that is geographically widespread. Lake sturgeon were incredibly abundant historically in Lakes Huron, Erie and Ontario, but stocks were decimated by overfishing. In Lake Huron, they remain in 9 of 15 U.S. tributaries with former spawning populations; 5 of those are well below minimum viable population levels, and 4 populations are considered stable. In Lake Erie, at least 6 former lake sturgeon spawning populations in tributaries on the U.S. side have been extirpated and the upper Niagara River has a small remnant population; the only robust population is in the Huron-Erie corridor, with spawning in the Detroit River, Lake St. Clair and the St. Clair River. In Lake Ontario, all of the former lake sturgeon spawning populations in tributaries on the U.S. side have either remnant spawning populations or are extirpated; small populations remain in the Black, Genesee, lower Niagara and Oswego rivers and in Oneida Lake. In the U.S. waters of the St. Lawrence River basin, lake sturgeon remain relatively common in a few areas (notably upper Lake St. Francis), however most former populations in the St. Lawrence River and its tributaries are remnant or extirpated.

In the upper Mississippi River basin, lake sturgeon went from being extremely plentiful historically to rare throughout the basin, with small populations now remaining in 10 tributaries. In the Missouri River basin, formerly abundant lake sturgeon populations declined drastically and were nearly extirpated by the early 1900s. Natural reproduction is either non-existent in Missouri or survival of young is not sufficient to increase population numbers, and lake sturgeon are now very rare in Missouri. In the Ohio River basin, lake sturgeon were formerly abundant throughout the Ohio River and many of its major tributaries, but populations were greatly reduced by 1950 and have suffered massive declines since the 1950s. Lake sturgeon are now nearly extirpated from the Ohio River and all of its major tributaries in Ohio, Kentucky, Indiana, Pennsylvania, West Virginia and Tennessee. Former lake sturgeon populations have been extirpated from the Allegheny, Cumberland, Ohio, Scioto, Tennessee and Wabash rivers. Only one small naturally reproducing population of lake sturgeon remains in the entire Ohio River basin, in the East Fork of the White River tributary of the Wabash River in southern Indiana. In the Arkansas-White River basin, very little is known about historical abundance of lake sturgeon. There have been two modern accounts of lake sturgeon in the White River, but the species is assumed to be essentially extirpated from Arkansas. In the lower Mississippi River basin, there is little historical information about lake sturgeon and no recent records. Stocking of hatchery lake sturgeon has occurred in the lower Mississippi River in Louisiana.

Only 6 lake sturgeon populations remain which have more than 1,000 adult fish; the Lake Winnebago system tributary to Lake Michigan (Lake Winnebago, Fox River, Wolf River and Lake Poygan); Black Lake/Black River in the Cheboygan River system, tributary to Lake Huron; the Huron-Erie corridor (Detroit River, Lake St. Clair and St. Clair River), tributary to Lake Erie; the Oswego River system tributary to Lake Ontario; Rainy River/Lake of the Woods in Northwestern Minnesota; and Yellow River/Yellow Lake, Wisconsin, in the upper Mississippi River basin.

Some important recovery measures are being implemented for lake sturgeon in some rivers, such as propagation and reintroduction into former habitats, dam removal or fish passage construction, and improved stream flows below dams. However, the legacy of overfishing and habitat destruction remains. Recovery efforts have not reached many areas, and many former spawning rivers are permanently blocked by dams. It will take many decades of effective habitat and harvest protections to rebuild viable lake sturgeon populations. The vast majority of former lake sturgeon spawning habitats are still inaccessible and many existing populations are isolated or fragmented. Lake sturgeon still face numerous threats from dams and hydroelectric facilities, pollution and contaminants, recreational fishing, poaching, invasive species, climate change, and habitat fragmentation.

The Center is petitioning for threatened status for all lake sturgeon in the United States, or alternatively for identification and listing of imperiled distinct population segments of lake sturgeon in the U.S. as endangered or threatened.

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NATURAL HISTORY

The lake sturgeon (*Acipenser fulvescens*) is an endemic North American fish species, historically distributed across the eastern and central United States and Canada. Lake sturgeon range from the Canadian waters of the Hudson Bay in Saskatchewan and Manitoba, east to the St. Lawrence River estuary, and from the Great Lakes and Mississippi River basins, to isolated populations farther south in the Tennessee River and Ohio River drainages.

Lake sturgeon are large, long-lived, and late-maturing. They can grow to over 8 feet long, weigh up to 300 pounds and attain ages of up to 100 years. Lake sturgeon have no scales but are covered by five rows of bony scutes on the back and sides.

Lake sturgeon prefer large shallow lakes and rivers and near shore habitats. They feed by using their protruding mouth to suction up bottom dwelling organisms such as crayfish and other crustaceans as well as insect larvae. Lake sturgeon are potamodromous (migrating in fresh water to spawn, typically from lake to stream), with high site fidelity.

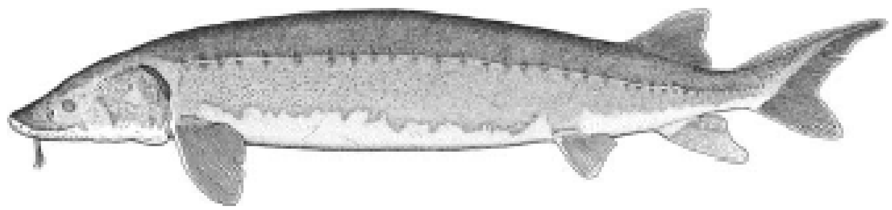
Lake sturgeon have a low reproductive rate and may not begin to spawn until they reach maturity at 15-25 years old. Male lake sturgeon reach sexual maturity at 15-20 years of age, at which point they spawn on average every other year. Females mature at about 20-25 years of age, but spawn on average only every three to four years. These reproductive characteristics reduce the rate of recovery of lake sturgeon populations that are overfished.

Description

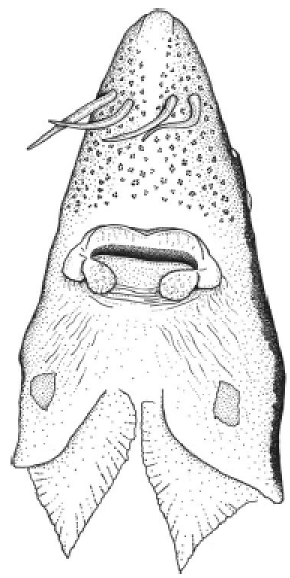
Sturgeons in general have a prehistoric appearance due to their large size, shark-like tails, and armored covering of bony plates. Sturgeons possess skeletons that are more cartilage than bone, have heavy, sandpaper-like skin, and are protected by rows of bony plates (called scutes) rather than scales. Underneath their flattened snouts are sensory barbels and a toothless “vacuum cleaner” mouth capable of siphoning up food.

Adult lake sturgeon are among the largest of North American freshwater fishes. Adult males generally measure between 100 and 185 cm long (3 to 6 feet) and weigh 11 to 30 kg (24 to 66 pounds), while the larger adult females range between 130 to 215 cm long (4 to 7 feet) and generally weigh from 25 to 100 kg (55 to 220 pounds) (Peterson et al. 2007). The largest documented lake sturgeon specimen, taken from Lake Michigan in 1943, measured 241 cm (nearly 8 feet) and weighed 141 kg (310 pounds) (Van Oosten 1956; Peterson et al. 2007).

The physical appearance of lake sturgeon is similar to that of most other sturgeon species. Lake sturgeon possess a torpedo-shaped, scaleless body that is protected by five lateral rows of scutes. The snout is pointed and features a protusible ventral mouth, which is used to suck prey into the mouth like a vacuum. Prey items are detected using four sensory barbels on the snout. Unlike other *Acipenser* species, the barbels of the lake sturgeon are situated closer to the tip of the snout than the origin of the mouth (Peterson et al. 2007). Lake sturgeon have a heterocercal tail, a large air bladder, and a single, large dorsal fin. The lake sturgeon’s vertebrae are cartilaginous and lack a centrum, and the notochord extends into the tail (Scott and Crossman 1973).



Basic morphology of adult lake sturgeon (from Peterson et al. 2007)

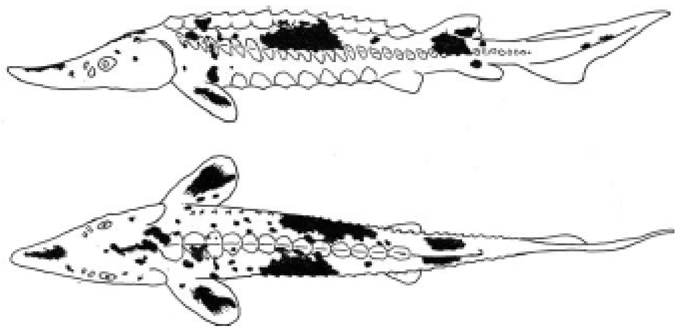


Ventral view of lake sturgeon head (from Peterson et al. 2007)

Lake sturgeon have five widely separated rows of scutes on the body. The dorsal row of scutes numbers 9 to 17, the two lateral rows have 29 to 42 scutes each, and the two ventral rows have 7 to 12 scutes each. The dorsal fin rays number 35 to 45, and the anal fin rays number 25 to 30 (Vladykov and Greeley 1963; Scott and Crossman 1973; Peterson et al. 2007). Body armoring is extensive on juveniles but decreases with age, with the scutes themselves being almost completely resorbed in adulthood. This contrasts with most anadromous sturgeons, which retain ossified scutes that grow throughout their life cycle (Peterson et al. 2007).

Lake sturgeon are generally dark brown or dark gray dorsally, with a similar but slightly lighter coloration on the lateral surfaces. The underside of lake sturgeon is typically white or cream-colored.

In juveniles smaller than 30 cm, two large black splotches are typically present across the dorsum and sides, which are not present in juveniles larger than 60 cm. In juveniles, black speckling on the upper surfaces of the body is common and often persists into early adulthood (Peterson et al. 2007). Juveniles have a series of bony plates in five rows (Scott and Crossman 1973).



Basic morphology and coloration of juvenile lake sturgeon (from Peterson et al. 2007)

Juvenile lake sturgeon (USFWS photo)

Taxonomy

Sturgeon are modern relicts of the ancient group of bony fishes, having remained relatively unchanged from when they first appeared 200 million years ago. Taxonomically, they belong to the infraclass Chondrostei, along with paddlefishes, numerous fossil fishes, and the ancestors of all other bony fishes. Sturgeons themselves are not ancestral to modern bony fishes but are a highly specialized and successful offshoot of the ancestral chondrosteans, retaining ancestral features such as a heteroceral tail, similar fin and jaw structure, and spiracle (breathing orifice).

The earliest members of the sturgeon group are thought to have evolved in the Lower Jurassic period, approximately 200 million years ago. However, the oldest fossils of the group date back to the Upper Cretaceous (Bemis et al. 1997). Most taxonomists currently agree that Acipenseriformes is a monophyletic group derived from the palaeonisciform fishes, a paraphyletic assemblage of early ray-finned fishes (Bemis et al. 1997).

The sturgeon family (Acipenseridae) is recognized as containing 27 species, distributed among four genera (Peterson et al. 2007). *Acipenser* is the largest of the genera within the family Acipenseridae and contains 17 species (Bemis and Kynard 1997). The common characteristics shared by members of the *Acipenser* genus are: a small, downward-projecting transverse mouth; a long, flattened snout that is either conical or narrow; a set of 4 cylindrical or fimbrated barbels; palatoquadratum connecting the symplecticum; stylohyale articulating with the posterior section of the symplecticuml linear arrangement of the palatoquadratum and the upper part of the maxillae; and clustered basihyalia positioned along the median line of the rostrum (Antoniu-Murgoci 1936a, 1936b, 1942; Peterson et al. 2007).

Five *Acipenser* species are native to North America. Of those, *Acipenser fulvescens* is the only species that completes its full life cycle in freshwater (Peterson et al. 2007). Although the lake sturgeon has always been placed within the genus *Acipenser*, it has undergone taxonomic changes – see the table below. Through the 19th and 20th centuries, at least 17 different names were assigned to the species and its various populations across the Great Lakes, St. Lawrence River and Central U.S. (Scott and Crossman 1973). By the 1950s, taxonomists had determined that these populations were in fact all part of a single species (Peterson et al. 2007). In accordance with the rules of scientific classification, the original species name (*Acipenser fulvescens*) was accepted as the official name for the species, which was first described by Constantine S. Rafinesque in 1817 (Peterson et al. 2007).

Synonym	Reference
Acipenser rubicundus	LeSueur 1818
Acipenser rupertianus	Richardson and Richardson 1836
Acipenser laevis	Agassiz 1850
Acipenser carbonarius	Agassiz 1850
Acipenser rhynchaeus	Agassiz 1850
Acipenser maculosus	LeSueur Günther 1870
Acipenser athracinus	Duméril 1870
Acipenser megalaspis	Duméril 1870
Acipenser lamarii	Duméril 1870
Acipenser atelaspis	Duméril 1870
Acipenser rosarium	Duméril 1870
Acipenser kirtlandi	Duméril 1870
Acipenser buffalo	Duméril 1870
Acipenser sturio	Eigenmann 1895
Acipenser fulvescens obtusirostris	Roussow 1955
Acipenser fulvescens acuitirostris	Roussow 1955

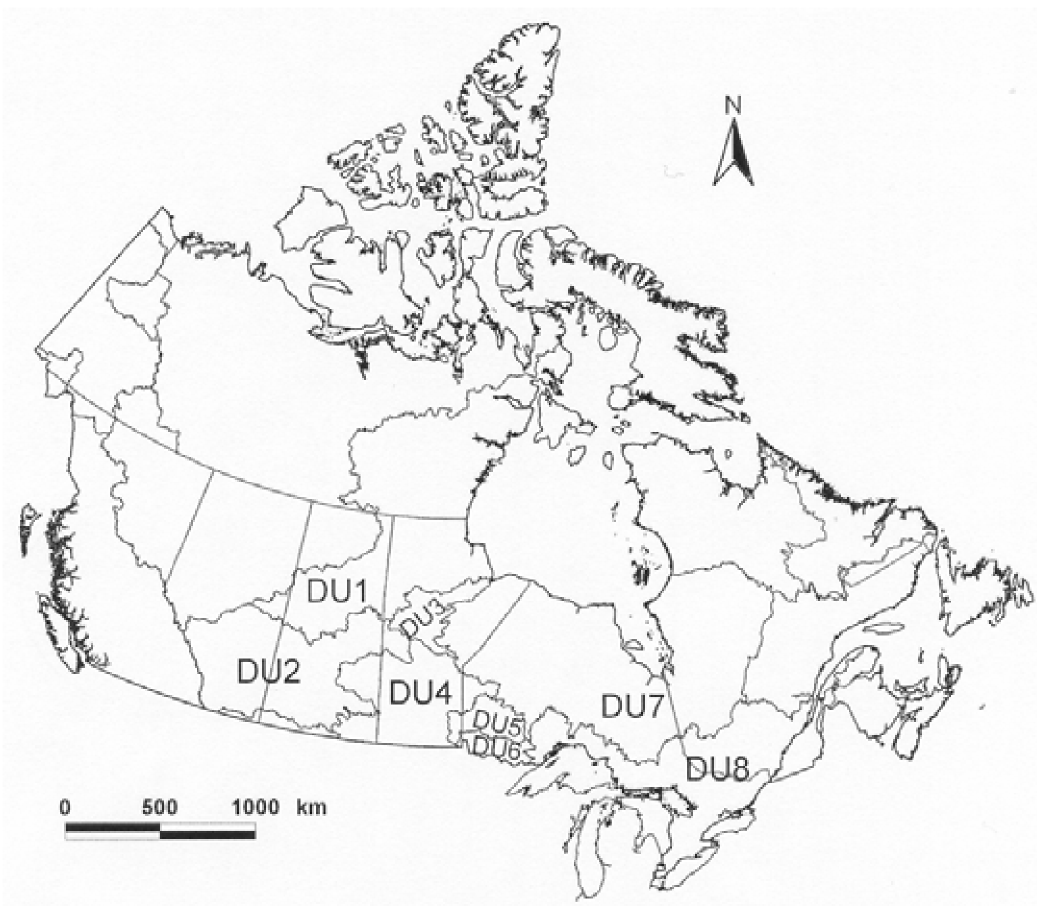
Previous synonyms for *Acipenser fulvescens* (from Galarowicz 2003)

Other common names for lake sturgeon have included freshwater sturgeon, Great Lakes sturgeon, Ohio sturgeon, rock sturgeon, rock fish, rubber nose, black sturgeon, dogface sturgeon, stone sturgeon, red sturgeon, ruddy sturgeon, common sturgeon, shell back sturgeon, bony sturgeon and smoothback (Galarowicz 2003).

Population Structure

Initial investigations into lake sturgeon genetic diversity and population structure primarily utilized mitochondrial DNA analysis and revealed very low levels of variation within and among populations (e.g. Guenette et al. 1993; Ferguson et al. 1993; Krieger et al. 2000; Scribner 2002). However the application of more polymorphic nuclear markers (microsatellites) has identified fine-scale structure within and among lake sturgeon populations in the Great Lakes basin and Hudson Bay. Studies indicate that there are genetic differences among lake sturgeon populations within the Great Lakes, and that genetic differentiation may even occur among larger watersheds (Ferguson et al. 1993; Fortin et al. 1993; Ferguson and Duckworth 1997; Robinson and Ferguson 2001; McQuown et al. 2003; Welsh and McClain 2004; DeHaan et al. 2006; Welsh et al. 2008).

Canada has designated endangered, threatened or special concern status for all of Canada's lake sturgeon populations. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) determined that lake sturgeon populations occurring in different major drainages appear invariably to be genetically distinct from each other (COSEWIC 2006). Based on published genetic studies and separation of populations by biogeographically distinct ecozones, COSEWIC (2006) determined there are at least eight distinct populations or "designatable units" of lake sturgeon in Canada, with many more populations undoubtedly present. However, Canada's criteria for designatable units requires "deep historical divergence," a different standard than the criteria for "distinct population segments" under the U.S. Endangered Species Act. Regardless, Canada recognizes designatable units of lake sturgeon in: 1) Western Hudson Bay, 2) Saskatchewan River, 3) Nelson River, 4) Red-Assiniboine Rivers-Lake Winnipeg, 5) Winnipeg River-English River, 6) Lake of the Woods-Rainy River, 7) Southern Hudson Bay-James Bay, and 8) Great Lakes-Upper St. Lawrence.



Lake sturgeon regional populations ("Designatable Units") recognized by Canada, based on genetic distinction and biogeographic zones (from COSEWIC 2006)
DU1 - Western Hudson Bay
DU2 - Saskatchewan River
DU3 - Nelson River
DU4 - Red-Assiniboine rivers-Lake Winnipeg
DU5 - Winnipeg River-English River
DU6 - Lake of the Woods-Rainy River
DU7 - Southern Hudson Bay-James Bay
DU8 - Great Lakes-Upper St. Lawrence

McQuown et al. (2003) used microsatellites to study samples from across the range of the current lake sturgeon distribution, but sampled a very small number of populations. McQuown et al. (2003) used differences in allele frequencies between regional stocks to sort populations in three distinct groups: Hudson Bay drainage, upper Great Lakes drainage, and lower Great Lakes–St. Lawrence River.

Scribner et al. (2004) found that lake sturgeon populations in western Lake Michigan (Menominee, Peshtigo, Oconto, lower Fox, and Wolf rivers, all tributaries to Green Bay) were genetically more similar to each other than to populations in eastern Lake Michigan (Manistee and Muskegon rivers), which, in turn were more similar to each other than to populations in Lake Huron tributaries.

DeHaan et al. (2006) used microsatellite data from eight disomic loci to assess genetic structure among 10 lake sturgeon populations in the Great Lakes basin and several of its tributaries; they detected evidence of significant substructure. More genetic variance was partitioned within individual lakes than among them. DeHaan et al. (2006) was able to assign these populations to three distinct assemblages, somewhat similar to those found by McQuown et al. (2003): Lake Superior drainages; western Lake Michigan; and eastern Lake Michigan and the eastern Great Lakes.

Drauch et al. (2008) observed significant levels of genetic divergence among lake sturgeon in the Ohio River basin, with large differences at both nuclear and mitochondrial markers between sturgeon in the White River in Indiana and sturgeon from 7 other sampled populations, suggesting that some degree of subdivision exists in the basin. Drauch et al. (2008) suggested that the White River lake sturgeon population is a genetically unique remnant stock that most likely survived mass extirpations in the Ohio River system. Drauch et al. (2008) also found that the Chippewa River lake sturgeon population (in the upper Mississippi River basin) is significantly differentiated from those in the White River at both microsatellite and mitochondrial loci, suggesting some amount of evolutionary independence between these populations.

Welsh et al. (2008) sampled sturgeon from 27 locations throughout the Great Lakes and found that lake sturgeon populations in the Great Lakes basin harbor substantial genetic diversity and that the majority of lake sturgeon populations are genetically distinct from each other (Welsh et al. 2008). Welsh et al. (2008) also concluded that lake sturgeon populations in Lake Superior are significantly different from those in the other Great Lakes. Welsh et al. (2010) defined six distinct genetic stocking units of lake sturgeon across the Great Lakes basin to be used for reintroduction efforts: northern Lake Superior, southern Lake Superior, northern Lake Huron, Green Bay, central Great Lakes (lower state of Michigan, Lake St. Clair, and the Niagara region) and the St. Lawrence area.

Homola et al. (2010) found a relatively high level of genetic divergence among lake sturgeon populations in tributaries of Lake Superior (Sturgeon River, Michigan and Bad River, Wisconsin) and Lake Michigan (Lake Winnebago system). Homola et al. (2012) identified 6 genetically differentiated spawning populations of lake sturgeon in Lake Michigan - in the Fox, Menominee, Oconto–Peshtigo, Kalamazoo, Manistee and Muskegon rivers.

Lake Superior Population Structure

DeHaan et al. (2006) detected evidence of significant substructure and a distinct genetic assemblage for lake sturgeon in Lake Superior drainages. Further genetic analysis by Welsh et al. (2008) provided evidence that lake sturgeon in Lake Superior and its tributaries may form a distinct population segment, differentiated from other Great Lakes lake sturgeon populations. Welsh et al. (2010) defined six genetic stocking units of lake sturgeon across the Great Lakes basin to be used for reintroduction efforts, including separate genetic assemblages for northern Lake Superior tributaries in Canada and southern Lake Superior tributaries in the U.S. Canada recognizes 8 genetically and geographically distinct populations of lake sturgeon in Canada, including a distinct sub-unit in the Canadian waters and tributaries of northern Lake Superior (COSEWIC 2006).

Lake Michigan Population Structure

Evidence for potentially distinct population segments of lake sturgeon in the Lake Michigan basin comes from genetic analyses by Scribner et al. (2004), DeHaan et al. (2006), Homola et al. (2010), Welsh et al. (2010) and Homola et al. (2012). DeHaan et al. (2006) detected evidence of significant substructure and distinct genetic assemblages for lake sturgeon populations in western Lake Michigan and eastern Lake Michigan. Scribner et al. (2004) found that lake sturgeon populations in western Lake Michigan tributaries to Green Bay (Menominee, Peshtigo, Oconto, Fox, and Wolf rivers) were genetically more similar to each other than to populations in eastern Lake Michigan (Manistee and Muskegon rivers), which in turn were more similar to each other than to populations in Lake Huron tributaries. Homola et al. (2010) found a relatively high level of genetic divergence among lake sturgeon populations in Wisconsin tributaries to Lake Superior (Sturgeon River and Bad River) and populations in the Lake Winnebago river system, a western tributary of Lake Michigan. Welsh et al. (2010) defined six genetic stocking units of lake sturgeon across the Great Lakes basin to be used for reintroduction efforts, including separate genetic assemblages for Green Bay tributaries in western Lake Michigan and a population in the central Great Lakes, which included the lower state of Michigan, as well as Lake St. Clair and the Niagara region. Homola et al. (2012) identified 6 genetically differentiated spawning populations of lake sturgeon in rivers tributary to Lake Michigan, in the Fox, Menominee, Oconto–Peshtigo, Kalamazoo, Manistee and Muskegon rivers. Although Homola et al. (2012) found high straying rates between river systems, the genetic data suggest that either individual sturgeon that stray are reproductively unsuccessful or that contemporary straying rates are not reflective of historical rates of gene flow. However, it is difficult to identify a distinct Lake Michigan population because lake sturgeon in western Lake Michigan are fairly similar to sturgeon in Lake Ontario/St. Clair, likely due to a postglacial re-colonization artifact (Welsh et al. 2008); and lake sturgeon in eastern Lake Michigan are fairly similar to sturgeon in Lake Huron (DeHaan et al. 2006; Welsh et al. 2010).

Lake Huron Population Structure

Scribner et al. (2004) concluded that lake sturgeon populations in Lake Huron tributaries were genetically differentiated from populations in tributaries of Lake Michigan, but the only Lake Huron samples studied were from Black Lake, St. Clair River and Lake St. Clair. Welsh et al. (2010) defined six genetic stocking units of lake sturgeon across the Great Lakes basin to be used for reintroduction efforts, including a separate genetic assemblage for northern Lake Huron. Canada recognizes 8 genetically and geographically distinct populations of lake sturgeon in Canada, and groups populations in Lake Huron with those in the other Great Lakes and St. Lawrence River basin (COSEWIC 2006). Because there is only one significant remaining lake sturgeon population in U.S. tributaries to Lake Huron (in Black Lake, in the Cheboygan River system), it is difficult to reach any conclusions about Lake Huron population structure.

Lake Erie Population Structure

McQuown et al. (2003) grouped samples of non-spawning lake sturgeon from Lake Erie and the Niagara River with populations from the St. Lawrence River basin, distinct from populations in Lake Michigan or Hudson Bay. DeHaan et al. (2006) found similar assemblages, assigning populations in Lake Erie to a larger population containing eastern Lake Michigan and the eastern Great Lakes. Canada recognizes 8 genetically and geographically distinct populations of lake sturgeon in Canada, and groups populations in Lake Erie with those in the other Great Lakes and St. Lawrence River basin (COSEWIC 2006). Welsh et al. (2008) found that populations in Lake Erie (St. Clair River and Detroit River) grouped with the rest of the Great Lakes except for Lake Superior. Welsh et al. (2010) defined six genetic stocking units of lake sturgeon across the Great Lakes basin to be used for reintroduction efforts, grouping populations in Lake Erie (St. Clair River and Detroit River) within a central Great Lakes population (lower state of Michigan, Lake St. Clair, and the Niagara region). Since there are no known remaining spawning populations in U.S. tributaries of Lake Erie – the only robust population is in the Huron-Erie corridor (Detroit River, Lake St. Clair and the St. Clair River, which are all connected waterways) – Lake Erie population structure is unknown.

Lake Ontario Population Structure

McQuown et al. (2003) grouped lake sturgeon populations from Lake Ontario (lower Niagara River) with populations from the St. Lawrence River basin, distinct from populations in Lake Michigan or Hudson Bay. DeHaan et al. (2006) found similar assemblages, assigning populations in Lake Ontario to a larger population containing eastern Lake Michigan and the eastern Great Lakes. Canada recognizes 8 genetically and geographically distinct populations of lake sturgeon in Canada, and groups populations in Lake Ontario with those in the other Great Lakes and St. Lawrence River basin (COSEWIC 2006). Welsh et al. (2008) found that populations in Lake Ontario (lower Niagara River and Black River) grouped with the rest of the Great Lakes except for Lake Superior, but lake sturgeon in Lake Ontario are also fairly similar to sturgeon in western Lake Michigan (DeHaan et al. 2006; Welsh et al. 2010). Welsh et al. (2010) defined six genetic stocking units of lake sturgeon across the Great Lakes basin to be used for reintroduction efforts, grouping populations in Lake Ontario (lower Niagara River and Black River) within a central Great Lakes population.

St. Lawrence River Population Structure

McQuown et al. (2003) grouped lake sturgeon populations from the St. Lawrence River basin (St. Lawrence River and Des Prairies River) with the lower Great Lakes. Canada recognizes 8 genetically and geographically distinct populations of lake sturgeon in Canada, and groups populations in the St. Lawrence River basin with those in the Great Lakes (COSEWIC 2006). Welsh et al. (2008) found that populations from the St. Lawrence River basin (St. Lawrence River, Grasse River and Lake Champlain) grouped with the rest of the Great Lakes except for Lake Superior. Welsh et al. (2010) defined six genetic stocking units of lake sturgeon across the Great Lakes basin to be used for reintroduction efforts, identifying a distinct St Lawrence River stocking unit, including sturgeon sampled from the St. Lawrence, Des Prairies, Black and Grasse rivers and Lake Champlain.

Northwestern Minnesota Population Structure

Lake sturgeon in the Red River and the Rainy River/Rainy Lake/Lake of the Woods in northern Minnesota are part of the larger Lake Winnipeg sturgeon population. Canada recognizes a Red-Assiniboine Rivers/Lake Winnipeg population of lake sturgeon (COSEWIC 2006).

Upper Mississippi River Population Structure

Drauch and Rhodes (2007) noted that not much was known about the historical genetic composition of lake sturgeon native to the Mississippi River basin. Drauch et al. (2008) determined that lake sturgeon from the Chippewa River in the upper Mississippi River basin are significantly differentiated from those in the White River in the Ohio River basin. Drauch and Rhodes (2007) noted that out of basin stocking of lake sturgeon (originating primarily from Lake Winnebago in the Great Lakes drainage) had occurred for 21 years in the upper Mississippi River. Restoration stocking since the late 1990s has mostly focused on using appropriately sourced sturgeon propagated from within the basin.

Missouri River Population Structure

Drauch and Rhodes (2007) noted that not much was known about the historical genetic composition of lake sturgeon native to the Missouri River. More than a decade of out of basin stocking of lake sturgeon (originating primarily from Lake Winnebago in the Great Lakes drainage) occurred in the Missouri River (Drauch and Rhodes 2007).

Ohio River Population Structure

Genetic analysis of the only remaining lake sturgeon population in the Ohio River basin, in the East Fork of the White River, indicates that it is a genetically unique remnant stock that survived mass extirpations in the Ohio River system (Drauch et al. 2008). Significant levels of genetic divergence were observed between White River fish and sturgeon from all other sampled Midwestern populations (Hudson Bay, Great Lakes Basin, Mississippi River and Ohio River), and population assignment tests revealed a single putative migrant in the White River, indicating the population has almost completely maintained its genetic integrity (Drauch et al. 2008). Drauch et al. (2008) found that lake sturgeon from the White River in the Ohio River basin are significantly differentiated from those in the Chippewa River in the upper Mississippi River basin.

Arkansas-White River Population Structure

No information can be located abut the historical genetic composition of lake sturgeon native to the Arkansas and White rivers.

Lower Mississippi River Population Structure

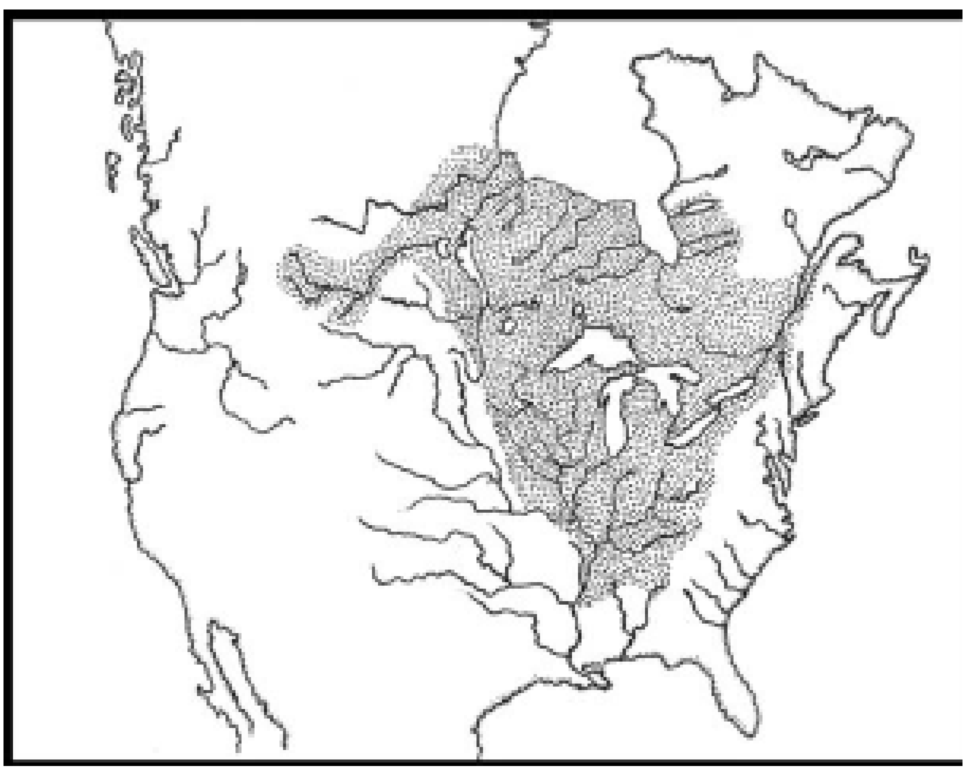
Drauch and Rhodes (2007) noted that not much was known about the historical genetic composition of lake sturgeon native to the Mississippi River.

Alabama-Georgia Population Structure

A former naturally reproducing lake sturgeon population in the Coosa River basin has been extirpated; reintroduced lake sturgeon in the Coosa River basin originated from stocking of sturgeon sourced from the Fox River system in Wisconsin.

Distribution

Historically, lake sturgeon were widely distributed across the eastern and central U.S. and Canada. Lake sturgeon were found in Canadian waters from Hudson Bay in Saskatchewan and Manitoba, east to the St. Lawrence River estuary and Lake Champlain. In U.S. waters they were distributed throughout the Great Lakes and their tributaries, and the Mississippi River basin, as well as in isolated populations farther south in the Tennessee River and Ohio River drainages and the Coosa River system in Alabama and Georgia (Harkness and Dymond 1961; Scott and Crossman 1973; NPSSC 1993; Williamson 2003; Freeman et al. 2005; Peterson et al. 2007). Few freshwater fish species had a wider geographic range in North America (COSEWIC 2006). Lake sturgeon remain distributed in three major North American drainages - the Mississippi River basin, the Great Lakes, and Hudson Bay - but occupy only a fraction of the waterways they once did (Hesse and Carreiro 1997).



Historic distribution of lake sturgeon (from Peterson et al. 2007)

Habitat

Lake sturgeon are potamodromous fish (migrating in fresh water from lake to stream), with high site fidelity (Swanson et al. 1991; Rusak and Mosindy 1997; Haxton 2003). In general, lake sturgeon occupy benthic habitats in large freshwater rivers and lakes (Becker 1983). Although there exist a couple of isolated cases where individual lake sturgeon have been taken from brackish water in the St. Lawrence River and in the Moose River near James Bay (Scott and Crossman 1973), and lake sturgeon can sometimes be found near the mouths of rivers in marine estuaries, as a rule the species spends its full life cycle in freshwater.

Lake sturgeon have been found over a variety of substrates, including mud, clay, sand, gravel, and silt, however a scientific consensus on their preferred habitat has not yet been reached. While one study found that lake sturgeon were typically associated with silt substrate and infrequently found over gravel or sand substrates (Lane et al. 1996), another study of lake sturgeon in the St. Lawrence River found that adult lake sturgeon were most often associated with boulder substrates, followed by silt, cobble, and coarse sand (Werner 2002). Spawning lake sturgeon can be found over a variety of substrate types as well, including boulder, cobble, gravel, sand, and clay (Lane et al. 1996), but spawning generally occurs over clean, rocky substrate with interstitial spaces, usually below rapids where the water is well oxygenated with upwelling flows (Auer 1996b; Bruch and Binkowski 2002). Popular spawning habitats for lake sturgeon are the mouths of large rivers, or below waterfalls, rapids, or dams that prevent further upstream migration (COSEWIC 2006; Kerr et al. 2011).

Habitats for juvenile lake sturgeon may be different than those of adult sturgeon. Juvenile lake sturgeon have been associated with sand substrates more often than adults (Seyler 1997; Benson et al. 2005; Smith and King 2005). Smith and King (2005) found that yearling and juvenile lake sturgeon were associated significantly with sand and organic substrate types but not with clay or sand-organic substrate. Seyler (1997) found young-of-the-year sturgeon over smooth sand and gravel substrates in less than a meter of water.

Given the discrepancies regarding sturgeon habitat substrates, it is likely that other factors act on lake sturgeon habitat selection. Water depth is likely a factor, as is water velocity. Adult lake sturgeon tend to be found at depths of 5-10 meters (COSEWIC 2006). Lane et al. (1996a) found that young-of-the-year sturgeon preferred 2.5 to 5+ meters of water. Juvenile lake sturgeon have been found to prefer low current velocities (0.32 m/s), possibly due to weaker swimming abilities (Benson et al. 2005).

Another likely determinant of lake sturgeon habitat is the availability of prey at a given site. Sturgeon are known to feed on benthic organisms, and juvenile sturgeon will remain in areas where there is moderate prey abundance rather than switching environments (Haxton 2003). Since many benthic organisms are found in areas characterized by sandy, clay substrate (Harkness and Dymond 1961; Haxton 2003; COSEWIC 2006; Peterson et al. 2007), these areas may be more desirable to sturgeon due to the prey community present.

Baril et al. (2017) used meta-analytical techniques to describe the mean and range of critical spawning habitat characteristics based on data from 48 sites across all major watersheds in which lake sturgeon are found. Data were compiled into univariate habitat suitability indices to describe the lake sturgeon spawning niche. Baril et al. (2017) results indicate that peak spawning suitability occurred at depth-averaged velocities of 0.6 m/s, depths of 0.55–0.85 m in small rivers (<100 m^3/s annual average discharge) and 0.75-5.25 m in large rivers (>100 m^3/s), over cobble substrates (64 – 256 mm) and that suitable water temperatures decreased with increasing latitude.

Although the majority of their data was retrieved from within the Great Lakes/St. Lawrence watershed, the Baril et al. (2017) comparison of mean suitability scores for the parameters of velocity, substrate, small river depth and large river depth for each watershed shows that the model performs well for all regions within the lake sturgeon range. This conclusion is further supported by the lack of significant differences across watersheds for the key habitat variables.

The Baril et al. (2017) study indicated that velocity, small and large river depth, and substrate size did not differ between watersheds or between published and unpublished sources of data. Spawning depth was greater in large than in small rivers, but river magnitude had no effect on velocity, substrate type, or water temperature. Interestingly, there was a negative correlation between the temperatures at which spawning occurs and a site's latitude, suggesting local adaptation of different populations to climatic conditions.

The Baril et al. (2017) overall findings were that spawning suitability peaked at velocities of 0.6 m/s, depths between 0.55-0.85 m in small rivers and 0.75–5.25 m in large rivers, with substrate size class of cobble similar to previous estimates. There was one notable exception to the results of Threader et al. (1998) for spawning habitat in slow moving Northern Ontario streams, which stated that sturgeon preferred to spawn in velocities over 1 m/s. High water velocities have been considered as critical habitat in much of the literature since (COSEWIC 2006; Pollock et al. 2015), with targets for spawning habitat restorations being as high as 0.8–1.5 m/s in Québec (Dumont et al. 2011). However, egg density at spawning sites decreases as current velocity increases from 0.6–1.1 m/s (LaHaye et al. 1992) and increases from 0.4–0.6 m/s (Johnson et al. 2006). The Baril et al. (2017) study supports these conclusions, suggesting that spawning habitat suitability peaks at 0.6 m/s, but can occur across a wide range of velocities.

Movement

Seasonal movements of lake sturgeon are not well known, but they probably move from shallower to deeper waters in summer to avoid warmer temperatures, returning to shallows when temperatures decline in winter (COSEWIC 2006). Lake sturgeon undergo spawning migrations, moving from lakes or large rivers to tributaries for spawning (Fortin et al. 1993; Rusak and Mosindy 1997; Auer 1999). It is believed that sturgeon imprint to their natal site (Boiko 1993) and return to these specific sites to spawn (Lyons and Kempinger 1992). Strong site fidelity is thought to occur, with many spawning lake sturgeon returning to the same sites year after year although the occasional fish may wander from lake to lake to spawn (COSEWIC 2006). After spawning sturgeon return downstream (Auer 1996a) but little is known about post-spawn movement patterns (Scott and Crossman 1973). It appears that lake sturgeon may home to post-spawning and overwintering sites (Auer 1996a; Knights et al. 2002).

Spawning migration can exceed distances of 100-200 km (Kempinger 1988; Rusak and Mosindy 1997; Auer 1999; COSEWIC 2006). After spawning, lake sturgeon typically return to their foraging sites (McKinley et al. 1998). Post-spawning movement up to 280 km from a spawning site has been documented in the Sturgeon River, Lake Superior (Auer 1999). Lake sturgeon may be capable of extremely long migrations (1,000-1,800 km) but are prevented by natural barriers and human alterations (Auer 1996a). Although lake sturgeon may reside in the same system throughout the year (Fortin et al. 1993), daily movements can be quite extensive, up to 6.8 km (Hay-Chmielewski 1987).

Some radio and sonar studies indicate that earlier life stages of lake sturgeon do not move as far as some of the larger, older individuals (Mosindy and Rusak 1991; Swanson et al. 1991; Benson et al. 2005; Smith and King 2005).

Recaptures of lake sturgeon in the Great Lakes reveal that some individuals have the ability to move between lake basins (for example between northern Lake Michigan and Lake Erie (MSU and MDNR 2015). However, genetic differences between populations that spawn in different Great Lake tributaries reveal that populations have been reproductively isolated from one another and that similarly to salmon, lake sturgeon tend to home to their natal rivers when they reach sexual maturity and spawn(MSU and MDNR 2015). Individuals that were produced in different rivers do not typically move randomly over large areas (MSU and MDNR 2015). Genetic data also suggest that lake sturgeon tend to use open lake waters in close proximity to their natal river - this trend is particularly evident for younger (pre-reproductive) individuals (MSU and MDNR 2015).

Kessel et al. (2018) investigated the spatial ecology of lake sturgeon within the barrier free Huron-Erie Corridor, which connects Lake Huron and Lake Erie. Movements of 268 lake sturgeon in the corridor were continuously monitored over 6 years (2011–2016) across the Great Lakes using acoustic telemetry. Kessel et al. (2018) identified 5 distinct migration behaviors, including year-round river residency and multiple lake-migrant behaviors that involved movements between lakes and rivers. Lake sturgeon in the corridor were found to contain a high level of intraspecific divergent migration, including partial migration with the existence of residents. Over 85% of individuals were assigned to migration behaviors as movements were consistently repeated over the study, which suggested migration behaviors were consistent and persistent in lake sturgeon. Differential use of specific rivers or lakes by acoustic-tagged lake sturgeon further subdivided individuals into 14 spatiotemporally segregated subgroups. Contingents associated with one river (Detroit or St. Clair) were rarely detected in the other river, which confirmed that lake sturgeon in the Detroit and St. Clair represent two semi-independent populations that could require separate management consideration for their conservation. The distribution of migration behaviors did not vary between populations, sexes, body size or among release locations, which indicated that intrapopulation variability in migratory behavior is a general feature of the spatial ecology of lake sturgeon in unfragmented landscapes.

Thayer et al. (2017) found that lake sturgeon show highly restricted over-winter movement and habitat use. Thayer et al. (2017) monitored over-winter movement of 86 lake sturgeon using a hydro-acoustic receiver array in the South Saskatchewan River, Canada. Lake Sturgeon showed strong aggregation and sedentary movement over-winter, demonstrating a temporal bottleneck. Movement was highly restricted during ice-on periods, with sturgeon seeking deeper, slower pools and having strong aggregation behavior. Although the sturgeon Thayer et al. (2017) studied had access to 1,100 kilometers of unfragmented riverine habitat, during the overwinter period 23 out of 86 (26%) of tagged lake sturgeon utilized a single, deep pool, representing less than 0.1%

of available habitat. The Thayer et al. (2017) study suggests that a substantial percentage of spawning adults spend the greater part of the year (~180 days) at specific overwintering locations, making this habitat potentially more critical to the survival of the population as a whole than any other habitat.

Feeding

Sturgeons in general are opportunistic predators that eat a variety of prey and switch foods as prey availability changes (Turner 1966). Sturgeon primarily feed on invertebrates in the benthic food chain, where most production occurs in large river systems (Sheehan and Rasmussen 1993). However, occasional pursuit and capture of active prey contradicts the image of sturgeon as merely sluggish bottom scavengers (Beamesderfer and Farr 1997). Lake sturgeon are generally not competitive with other bottom-feeders as they tend to feed in different areas (Scott and Crossman 1973). To detect prey, lake sturgeon swim along the bottom of lakes or rivers and use their sensory barbels in contact with the substrate; once prey items are detected, lake sturgeon suck them in by rapidly extending their protractible mouth, and then food items are strained while substrate materials are expelled through the mouth or gills (Harkness and Dymond 1961; Peterson et al. 2007).

Diet composition varies among systems depending on prey availability (Magnin and Harper 1970; McKinley et al. 1993). Lake sturgeon diets commonly include crayfish, mollusks, dipterans (especially chironomids), snails, ephemeropterans (including *Hexagenia* spp.), trichopterans, neuropterans, fish eggs, nematodes, leeches, amphipods, decapods, zebra mussels, and, rarely, fish (Harkness 1923; Hay-Chmielewski 1987; Houston 1987; Choudhury et al. 1996; Kempinger 1996; Chiasson et al. 1997; Beamish et al. 1998; Jackson et al. 2002). *Daphnia* sp. and *Leptadora* sp. were found in diets of adults during the summer in Lake Winnebago, Wisconsin (Choudhury et al. 1996). Feeding activity occurs throughout the year (Priegel and Wirth 1971) but ceases during spawning (Houston 1987).

Young-of-year sturgeon prey on small crustaceans, chironomid larvae, trichopterans and ephemeropterans (especially *Baetidae*) (Harkness and Dymond 1961; Eddy and Underhill 1974; Choudbury et al. 1996; Kempinger 1996). Studies performed in the St. Lawrence River found that lake sturgeon within the smallest size classes (300-650 mm) demonstrated a prey preference for chironomid and amphipod larvae, with some minor consumption of caddisfly larvae (Werner 2002; Nilo et al. 2006). Other studies have shown that juvenile lake sturgeon in this area had a highly diversified diet composed of at least 75 taxa. The most commonly exploited prey were amphipods, aquatic insect larvae, mollusks, and oligochaetes. Fish and microcrustaceans were also eaten, but in much smaller proportions (COSEWIC 2006).

Adult lake sturgeon are physically capable of exploiting a larger forage base and therefore have a greater range of dietary preference, with increased predation on mollusks. As Great Lakes sturgeon increase in size, mussels often become a preferred prey item and may even be foraged to the exclusion of other prey (Werner 2002). In contrast, Chippewa River sturgeon were found to feed largely on small snails (Becker 1983) and in Lake of the Woods, mayfly larvae and crayfishes composed 70 percent of food items found in commercially harvested lake sturgeon. Sculpins, sticklebacks, and other small benthic fish species have also been occasionally reported in lake sturgeon diets, though the extent of their use is unknown (Mosindy and Rusak 1991; COSEWIC 2006).

Reproduction and Growth

Lake sturgeon have long life spans and late maturity (Houston 1987). Female lake sturgeon can reach sexual maturity between 14 and 33 years of age (typically between 20 to 28 years) and males tend to reach sexual maturity between 8 and 16 years of age, though it can take up to 22 years (Harkness and Dymond 1961; Priegel and Wirth 1974; USFWS 2006). Estimations of generation time vary between 26 to 30 years (Fortin et al. 1996; Scott and Crossman 1998) to up to 35 to 54 years (COSEWIC 2006). The latter has been calculated in consideration of a lifespan of approximately 55 to 80 years and an estimate of the mean age for the onset of sexual maturity of 16.8 years for males and 25.8 years for females (COSEWIC 2006).

Males and females differ in spawning periodicity. While males spawn every 1 to 3 years (most commonly every second year), females spawn every 3 to 8 years (Priegel and Wirth 1977; Lyons and Kempinger 1992; Wallace 1991; Fortin et al. 2002; COSEWIC 2006). An estimated 10 to 20 percent of adult lake sturgeon within a population are sexually active and spawn during a given season (USFWS 2006).

Lake sturgeon spawning generally occurs from April to early June (Scott and Crossman 1998; Fortin et al. 2002; Forsythe et al. 2011). In the Black River, Michigan, lake sturgeon spawn in two distinct groups: early spawners (late April and early May), when the water temperatures are colder and when river flows are generally higher and more variable due to melting snow and spring rains; and late spawners, later in May and early June (Forsythe et al. 2011). Sturgeon in the same river reach may be effectively reproductively isolated due to consistent differences in spawning time (Forsythe et al. 2011). Lake sturgeon spawn in rivers with a water depth of 1.5-3.5 meters and water current velocity ranging from 0 to greater than 10 m/s (Scott and Crossman 1973; Bruch and Binkowski 2002; Smith 2003). Spawning occurs over clean, rocky substrate with interstitial spaces, usually below rapids where the water is well oxygenated with upwelling flows (Auer 1996b; Bruch and Binkowski 2002). When not in riverine habitats, lake sturgeon prefer to spawn along lake shorelines with relatively strong currents (>0.15 m/s) and shallow water (Kempinger 1988). In lakes where suitable spawning habitat is not available, lake sturgeon will spawn over ledges or islands where wave action produces the level of oxygenation required for the eggs (Houston 1987).

Although spawning activities have been observed during day and night time at a wide range of temperatures (Bruch and Binkowski 2002), specific spawning activities seem to be highly dependent on water temperature and can vary widely among years and systems. Spawning has been noted to occur at water temperatures between 8.3-23.3 ºC (Kempinger 1988) or 10-18°C (Scott and Grossman 1973; LaHaye et al. 1992; Seyler 1997; COSEWIC 2006), with peak spawning observed at 10-14 ºC (Kempinger 1988) or 11-16°C (LaHaye et al. 1992; Bruch and Binkowski 2002; COSEWIC 2006). Slight decreases in water temperature (1.5-3.0 ºC) can result in cessation of spawning (Kempinger 1988). Spawning can occur within two different periods in the same year if water temperatures fluctuate, although the first period is more intensive (Kempinger 1988; LaHaye et al. 1992; Auer and Baker 2002). Water level and flow also appear to influence spawning (Auer and Baker 2002).

Males appear on spawning sites first (Harkness and Dymond 1961; Priegel and Wirth 1977; Folz and Meyers 1985; Lyons and Kempinger 1992) and cruise the area (Bruch and Binkowski 2002). Males exhibit porpoising behaviors, and spawning activity begins after females move to the site (Bruch and Binkowski 2002). During spawning, 1-2 males are often paired with each female and females lie together in small groups of 2-3 (Harkness and Dymond 1961). Up to 6-8 males have been observed fertilizing the eggs of one female (Kempinger 1988). While female sturgeon are in spawning condition for only a brief period of time, they don't always release all of their eggs in one act. Instead, many females spawn over multiple days (Harkness and Dymond 1961).

Spawning surveys conducted in Black Lake, Michigan in 2012 and 2013 monitoring 247 and 271, respectively, adult lake sturgeon indicated that females spent between 1 to 23 days on the spawning grounds, with 60% of females spending only one day (LHLSWG 2017). Retention time (the number of days on the spawning grounds) was influenced by initial arrival date, mean temperature, maximum discharge, and the number of males with the availability of mates having the largest influence (LHLSWG 2017).

Females may release from 50,000 to more than 1 million eggs that are black in color, glutinous, adhesive, and approximately 3 mm in diameter (Harkness and Dymond 1961; Cuerrier 1966; Priegel and Wirth 1971; Becker 1983; Fortin et al. 1992; Fortin et al. 2002; USFWS 2006). Lake sturgeon are "lithophilic spawners" - broadcasting eggs onto rocks and into crevices on the river bottom. Eggs are scattered, drift downstream, and adhere to rocks or other objects in the water column and receive no parental care (Kempinger 1988).

Larvae hatch from 5-18 days after spawning, dependent upon water temperature, and when eggs are 8-12 mm in size (Kempinger 1988; LaHaye et al. 1992; MSU and MDNR 2015). Typically, eggs that incubate in colder temperatures take longer to hatch than those incubated in warmer temperatures (MSU and MDNR 2015). Hatching success is low, typically less than 1% (Kempinger 1988).

As sturgeon hatch, the "free embryo" immediately burrows further into the substrate to find cover or refuge while utilizing yolk-sac reserves; after their yolk-sac is absorbed, which usually takes up to 5 to 7 days depending upon temperature, the embryo begins exogenous feeding which is the onset of the larval period (MSU and MDNR 2015). As lake sturgeon begin exogenous feeding, they emerge from the substrate as larvae and disperse downstream to suitable larval rearing areas (MSU and MDNR 2015). Larvae are negatively buoyant until formation of the swim bladder, about 60 days post-hatch (COSEWIC 2006). Larval drift occurs at night and begins about 2 weeks after the first spawning activities (COSEWIC 2006). It is believed that larval lake sturgeon inhabit natal rivers during this life period until they reach the first year or two of the juvenile period; mortality for larvae is significant due to the lack of habitat which provides cover for drifting larvae from predators (MSU and MDNR 2015). In Great Lakes tributaries, juvenile sturgeon are likely to remain in the lower reaches of natal rivers until the fall, when they disperse to lake habitats (MSU and MDNR 2015).

The sex ratio in lake sturgeon is approximately 1:1 at birth, but quickly widens after maturation (Mosindy and Rusak 1991; Fortin et al. 1993). Some studies have found the ratio to be anywhere between 2:1 females to males by the age of maturation (20-29 years) and 6:1 by the age of 40 (Dumont et al. 1987; Fortin et al. 1993).

Lake sturgeon grow rapidly through the first spring and summer of life. During the juvenile phase individuals develop a bony exterior and become less vulnerable to predation by most fish predators; mortality during the first winter is fairly high but thereafter annual probabilities of survival are high (MSU and MDNR 2015). Growth is characterized by rapid juvenile growth rates, but rates decline when adults become sexually mature (Harkness and Dymond 1961; Beamesderfer and Farr 1997). Growth varies among systems and years (Priegel and Wirth 1971; Jackson et al. 2002,) and has been attributed to a variety of abiotic and biotic factors. In general, size and growth rates decrease with latitude and water temperature (Fortin et al. 1996; Power and McKinley 1997) but increase in more alkaline and conductive waters (Fortin et al. 1996). No difference in growth rates has been demonstrated between riverine and lacustrine habitats (Power and McKinley 1997). Growth also varies with food availability (Houston 1987; Noakes et al. 1999).

Historically, lake sturgeon were thought to have a lifespan of approximately 55 years for males, and 80-150 years for females (USFWS 2006). Individuals were thought to reach maturity at a length of at least 1.15 meters and were often found up to or in excess of 2 meters (Haxton 2003). Lake sturgeon can grow to extremely large sizes, for example, an adult lake sturgeon was captured in 1903 in the Roseau River measuring 3.6 meters and weighing 204 kilograms. However, most sexually mature sturgeon that are found today are less than 2 meters in length and less than 36 kg in weight (Dumont et al. 1987; Scott and Crossman 1998). This smaller size indicates that the lifespan of lake sturgeon may be shifting in response to new threats or simply that habitat conditions are not allowing them to reach large size, with potential negative demographic consequences.

Natural Mortality

Common natural predators of lake sturgeon eggs are native crayfish (*Orconectes* spp.), mudpuppies (*Necturus maculosus*), sucker species (*Catostomidae*), logperch (*Percina caprodes*), yellow perch (*Perca flavescens*) and redhorse (*Moxostoma* spp.), as well as adult lake sturgeon (Kempinger 1988; Nichols et al. 2003; Caroffino et al. 2010). During the egg period, developing lake sturgeon are also vulnerable to non-native predators, which are discussed in the section on disease and predation below. There are also microbes and fungi that attack developing sturgeon embryos. Larval lake sturgeon mortalities can be high (USFWS 2006). Young-of-the-year sturgeon are most likely to be preyed upon by other fish species, and have been found in the gut contents of walleye (*Sander vitreus*) in the lower Abitibi River in Ontario (Seyler 1997). However, natural mortality due to predation is not likely to be a major factor after the first year of life, as scutes protect young sturgeon and older fish are protected by their large size (Scott and Crossman 1973; Houston 1987).

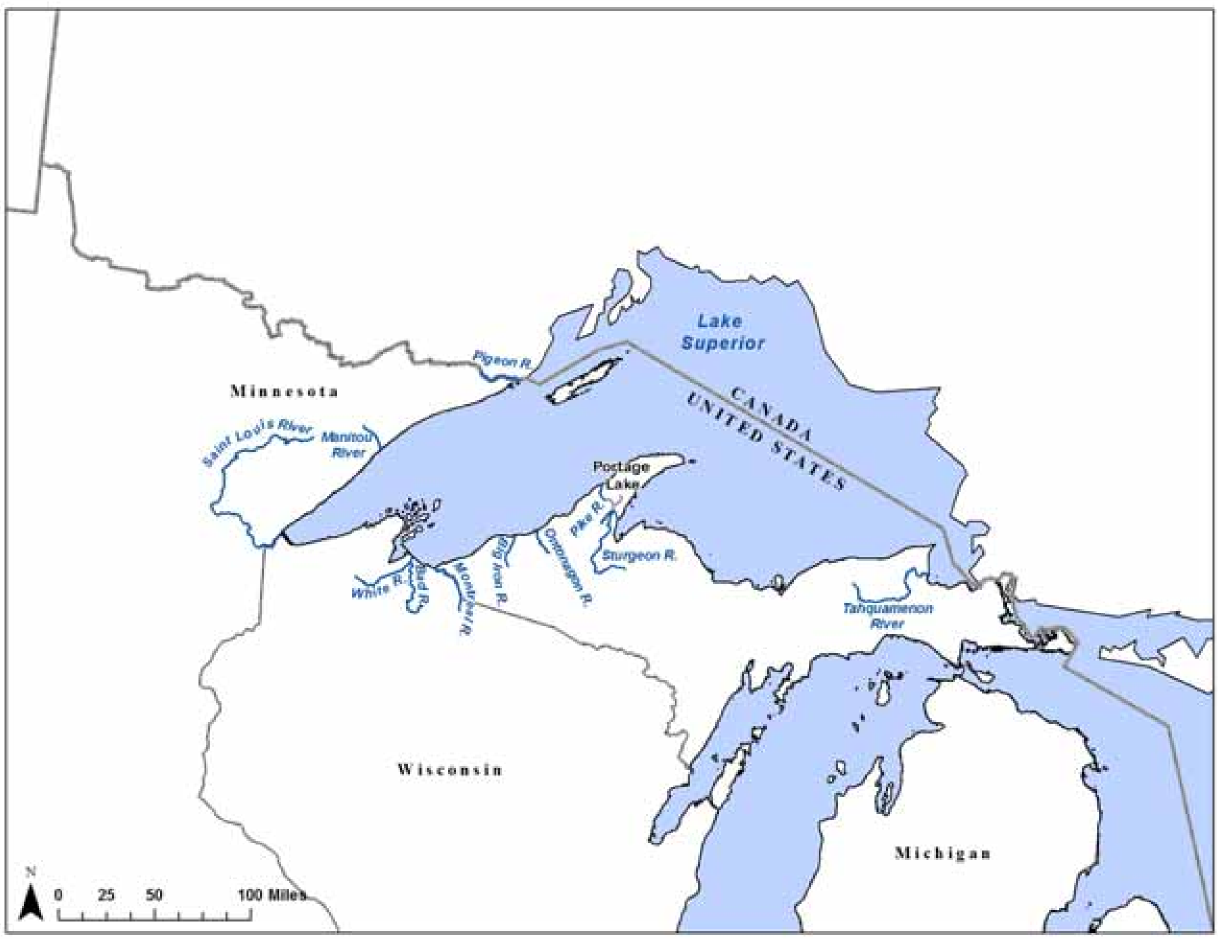
Natural mortality of adult lake sturgeon tends to be low in areas that are not affected by anthropogenic factors and threats; however there are now few such areas remaining for lake sturgeon. Adult lake sturgeon are not considered to have any natural predators, although historically they may have been vulnerable to black bears (*Ursus americanus*) while spawning in shallow waters (COSEWIC 2006).

STATUS

Historic and Current Distribution and Abundance

Great Lakes

Lake Superior



U.S. tributaries of Lake Superior with former and current lake sturgeon spawning populations

Basin-wide Distribution and Abundance

Lake sturgeon were historically extremely abundant in Lake Superior: Based on harvest records, Hay-Chmielewski (1997) estimated that there were 57,000 lake sturgeon weighing more than 50 pounds in Lake Superior in 1840; and Haxton et al. (2014) estimated that the biomass of lake sturgeon in Lake Superior was 2.13 million pounds in 1885. Lake sturgeon were likely past their peak harvest when commercial harvest records were first documented for Lake Superior, indicating that the estimate by Haxton et al. (2014) is below the real unexploited historical standing stock. Lake Superior sturgeon stocks collapsed in the early 1900s (Auer 2003). Current lake sturgeon abundance in Lake Superior is just a fraction of historic levels (Hayes and Caroffino

2012). Basic abundance and biological data is unavailable for many stocks in Lake Superior (Elliott et al. 2008).

At least 22 tributaries of Lake Superior in the U.S. and Canada historically supported spawning populations of lake sturgeon (Harkness and Dymond 1961; Auer 2003; Zollweg et al. 2003; Quinlan 2007; Pratt 2008). Former spawning populations in 7 of 9 tributaries (78%) on the U.S. side (the Manitou, St. Louis, Ontonagon, Montreal, Big Iron, Pigeon and Tahquamenon rivers) have been extirpated (Auer 2003; Zollweg et al. 2003; Pratt 2008). In the U.S., successful natural reproduction and small, self-sustaining populations of lake sturgeon now occur only in the Sturgeon River and its tributary Otter River (estimated 200-400 spawners annually), and the Bad River and its tributary White River (estimated 250-350 spawners annually). Lake sturgeon have since been restocked in the St. Louis and Ontonagon rivers but there has been limited evidence of spawning and the population sizes are extremely small or unknown (Baker 2006; Pratt 2008; Hayes and Caroffino 2012; Cook 2015).

On the Canadian side of Lake Superior, former lake sturgeon spawning populations have been extirpated from 7 tributaries (Pigeon, Wolf, Gravel, Prairie, White and Harmony rivers and Stokely Creek). Remaining populations in 8 Canadian tributaries (Kamanistikwia, Black Sturgeon, Nipigon, Pic, Michipicoten, Batchawana, Chippewa and Goulais rivers) are all small, with unknown population sizes (Holey et al. 2000; Auer 2003). A 2001 population estimate for the Kaministiquia River was 188 adult fish for 12 km of river surveyed (Friday and Chase 2006); a 2003-2004 population estimate for the Black Sturgeon River was 96-103 adult spawning fish (Friday 2006); very low numbers (9-20 fish) of sturgeon were caught during spring assessment netting on the Goulais River from 2000-2004 (Chase 2006); and a spring 2002 survey of the Big Pic River and its tributaries captured only 19 sturgeon (COSEWIC 2006). Kelso and Cullis (1996) reported that lake sturgeon were extirpated from Nipigon Bay of Lake Superior, however Welsh has received recent samples of lake sturgeon from Nipigon (A. Welsh, pers. comm., 2016). Pratt (2008) attempted to re-evaluate many of the extant Canadian populations and was only able to gather population estimates for the Kaministiquia and Black Sturgeon rivers, which had much lower numbers of sturgeon than reported by Auer (2003).

Pigeon River, Minnesota/Ontario

The Pigeon River flows into northwestern Lake Superior, and forms part of the Canada–United States border between Minnesota and Ontario.

Historically there was a spawning population of lake sturgeon in the Pigeon River, but it has been extirpated (Holey et al. 2000; Auer 2003). A single adult lake sturgeon was observed in the Pigeon River in 1964 but there has been no recent evidence of spawning (Auer 2003; Zollweg at al. 2003).

Manitou River, Minnesota

The Manitou River flows into northwestern Lake Superior.

A former lake sturgeon spawning population in the Manitou River has been extirpated (Holey et al. 2000; Zollweg et al. 2003).

St. Louis River, Minnesota/Wisconsin

The St. Louis River flows through Minnesota and Wisconsin into western Lake Superior.

Lake sturgeon historically had access for spawning in the St. Louis River up to a natural falls at Jay Cooke Park, 22 km upstream from Lake Superior (Auer 1996a).

Lake sturgeon populations in the St. Louis River declined dramatically in the late 1800s, and by the early 1900s had been extirpated due to the combined effects of exploitation, pollution and habitat alteration (Schram et al. 1999; Auer 2003).

Since the lake sturgeon decline, exploitation in Lake Superior has been reduced, water quality in the St. Louis River has improved, and the upper-estuary spawning habitat has remained relatively unchanged and is adequate (Schram et al. 1999).

In attempts to reestablish a lake sturgeon population, the Wisconsin Department of Natural Resources (WDNR) began annual stocking of lake sturgeon fry, fingerlings and yearlings in the St. Louis River in 1983 (Schram et al. 1999). Stocked fish were the Lake Winnebago strain from the Wolf River (Schram et al. 1999; Scheidegger 2000; Auer 2003). Between 1983 and 2000, WDNR stocked 16 sturgeon year-classes (Abraham and Kallak 2008). Because of genetic concerns with the stocking of fish from outside the Lake Superior basin, the restoration efforts were curtailed for several years; since 1998 stocked sturgeon have been propagated from the Sturgeon River, an intrabasin source (Scheidegger 2000).

Schram et al. (1999) evaluated these stocking efforts and found that the stocked (non-spawning) lake sturgeon ranged in Lake Superior from the St. Louis River 145 km east to the Apostle Islands in Wisconsin and 110 km northeast to Little Marais in Minnesota. Sturgeon abundance in the St. Louis River estuary and western Lake Superior increased due to the stocking program and stocked juveniles were regularly captured in fisheries assessments in the area, but there was no evidence of lake sturgeon spawning in either the lower or upper St. Louis River (Schram et al. 1999; Zollweg et al. 2003; Welsh 2004; Pratt 2008).

In 2007, WDNR observed mature sturgeon returning from Lake Superior to historical spawning grounds in the St. Louis River, but did not observe spawning (Abraham and Kallak 2008). Since 2011, WDNR, Minnesota DNR and the Fond du Lac Band of Lake Superior Chippewa have documented a few sturgeon fry and one 24-inch-long juvenile sturgeon in the lower river, below the Fond du Lac Dam, the first evidence of successful sturgeon spawning in the St. Louis River since stocking began (Cook 2015).

Bad River, Wisconsin

The Bad River flows into southwestern Lake Superior in northern Wisconsin.

Lake sturgeon historically had access for spawning in the Bad River up to a natural falls 32 km upstream from Lake Superior (Auer 1996a).

The Bad River currently supports a small, self-sustaining lake sturgeon population, but abundance is reduced from historical levels (Auer 2003). Lake sturgeon taken from the Bad River have been propagated and returned to the Bad River to augment the population (Auer 2003). Holey et al. (2000) estimated an annual spawning run of about 350 lake sturgeon. Zollweg et al. (2003) estimated an annual spawning population of about 250 fish. In 2010, the Bad River total adult population size (not the annual spawning population) was estimated at 666 sturgeon (Schloesser and Quinlan 2010).

White River, Wisconsin

The White River is a tributary of the Bad River in Wisconsin, which joins the Bad River just above its mouth at Lake Superior.

The White River also currently supports a small, self-sustaining lake sturgeon population, but abundance is reduced from historical levels (Auer 2003). The genetic structure of the Bad River and White River spawning populations was found to be similar to each other, but highly differentiated from all other spawning populations in Lake Superior (Welsh et al. 2008). Zollweg et al. (2003) estimated an annual spawning run of only 15 or more fish. In 2010, the White River adult lake sturgeon population size (not the annual spawning population) was estimated at 178 sturgeon (Schloesser and Quinlan 2010).

Montreal River, Wisconsin/Michigan

The Montreal River is a southern tributary of Lake Superior in northern Wisconsin and the Upper Peninsula of Michigan.

Historically, lake sturgeon spawned in the Montreal River (Hay-Chmielewski and Whelan 1997; Holey et al. 2000; Zollweg et al. 2003; Pratt 2008). This population of lake sturgeon has been extirpated from the Montreal River (Holey et al. 2000; Zollweg et al. 2003; Pratt 2008).

Big Iron River, Michigan

The Big Iron River is a southern tributary of Lake Superior on the Upper Peninsula of Michigan (Hay-Chmielewski and Whelan 1997).

A former spawning population of lake sturgeon in the Big Iron River has been extirpated (Hay-Chmielewski and Whelan 1997).

Ontonagon River, Michigan

The Ontonagon River flows into southern Lake Superior on the western Upper Peninsula of Michigan.

Lake sturgeon were extirpated from the Ontonagon River in the 1800s (Auer 2003; Zollweg et al. 2003; Pratt 2008). Lake sturgeon access to historic spawning grounds in the Ontonagon River is blocked by Victoria Dam, 8 km upstream from Lake Superior (Auer 1996a).

A single adult lake sturgeon was seen in the Ontonagon River in 1994 (Auer 2003), but several subsequent years of sampling in the mid-1990s failed to capture any lake sturgeon and the population was assumed to be extirpated (Baker 2006).

Lake sturgeon have been reintroduced to the Ontonagon River (Holey et al. 2010), which was stocked with hatchery fish from 1998-2002 and 2004, including sturgeon from the nearby Sturgeon River (Auer 2003; Baker 2006). Subsequent sampling in the Ontonagon River and nearby areas of Lake Superior captured juvenile lake sturgeon of hatchery origin (Filmore 2003). Surveys from 2001-2005 by Baker (2006) did not find any adult or larval lake sturgeon, but captured 110 juvenile lake sturgeon (age-0 and yearling, 14–66 cm TL) in the lower Ontonagon River over soft substrates of sand and silt, implying potential spawning of stocked fish. Hayes and Caroffino (2012) estimated the annual spawning population in the Ontonagon River to be less than 25 adults, far below a minimum viable population size. The Michigan Department of Natural Resources plans to continue stocking propagated lake sturgeon into the Ontonagon River until 20 year classes have been added.

Sturgeon River, (Houghton County) Michigan

The Sturgeon River (Houghton County) flows into southern Lake Superior through the Keweenaw Peninsula at Portage Lake.

Lake sturgeon access to historic spawning grounds in the Sturgeon River is blocked by Prickett Dam, 69 km upstream from Lake Superior (Auer 1996a). An impassable natural falls exists 6 km above the dam (Auer 1996a).

The Sturgeon River currently supports a small, self-sustaining lake sturgeon population, but abundance is reduced from historical levels (Auer 2003). Lake sturgeon spawn in only two locations in rapids below Prickett Dam (Auer 1996b, 1999). Small numbers of lake sturgeon were reported in the Sturgeon River from 1970-1980 below Prickett Dam (Baker 1980). The total lake sturgeon population (not the annual spawning population) in the Sturgeon River in 1993 was estimated at 375 fish (Hay-Chmielewski and Whelan 1997).

Holey et al. (2000) estimated an annual Sturgeon River spawning run of about 200 lake sturgeon. Galarowicz (2003) reported a “healthy” lake sturgeon population in the Sturgeon River. Zollweg et al. (2003) characterized the Sturgeon River lake sturgeon population as “remnant” with an estimated annual spawning run of about 200 fish. Using sonar technology, the spawning population was estimated in 2004 at 350-400 lake sturgeon (Auer 2008). During surveys from 1996-2005, Baker (2006) captured 446 lake sturgeon (TL 106–178 cm) in the Sturgeon River and confirmed spawning (695 larvae captured and spawning adults observed). Baker (2006) noted that the population appears to be self-sustaining. Using mark-recapture analysis, Hayes and Caroffino (2012) estimated a total population size (not the annual spawning population) of 1,808 lake sturgeon in the Sturgeon River, with a stable population trend.

Otter River/Otter Lake

A landlocked lake sturgeon population persists in Otter Lake (Baker 1980; Hay-Chmielewski and Whelan 1997), in the Otter River tributary of the Sturgeon River. Baker (2006) confirmed spawning in the Otter River tributary, observing lake sturgeon eggs on river substrate during a visual survey for spawning adults during May 2002.

Pike River

The Pike River converges with the Sturgeon River at Portage Lake.

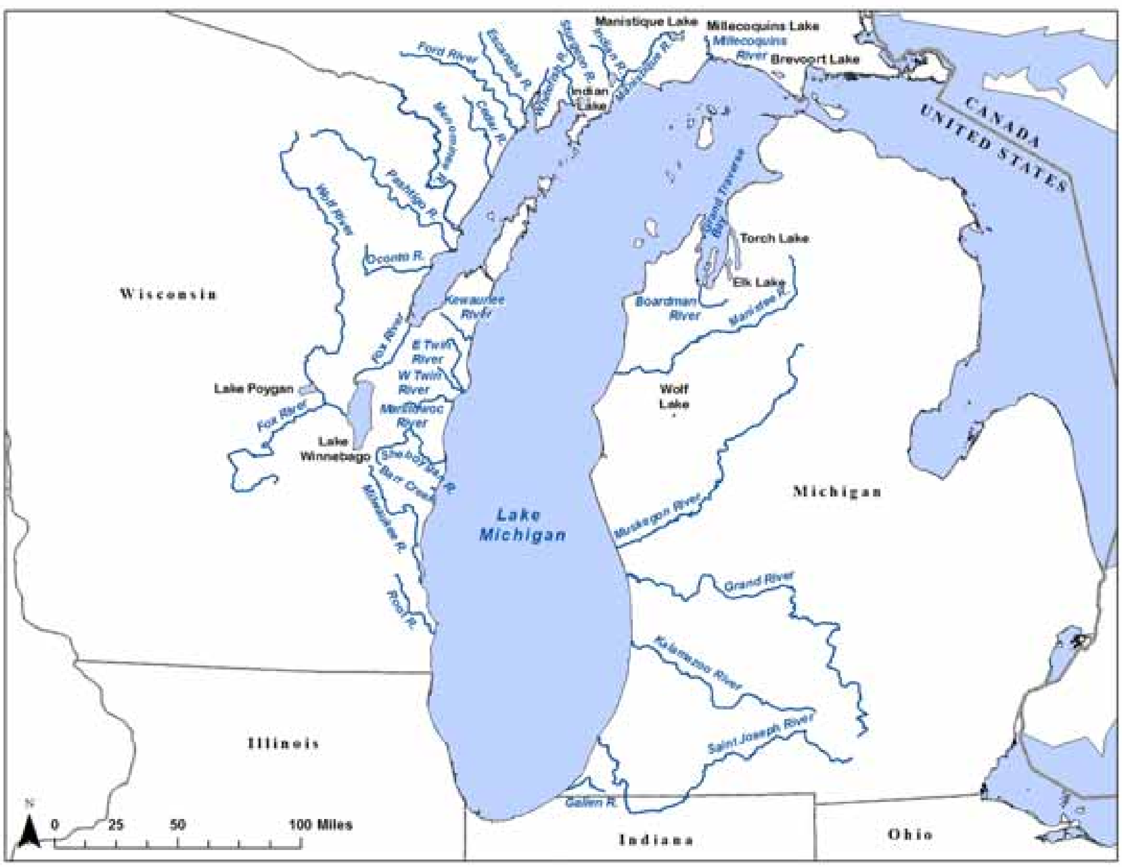
The Pike River is thought to have a small, remnant population of an unknown number of lake sturgeon, but it is unknown if there is any spawning (Holey et al. 2000; Zollweg et al. 2003).

Tahquamenon River, Michigan

The Tahquamenon River flows into southeastern Lake Superior from the eastern end of the Upper Peninsula of Michigan.

Lake sturgeon formerly spawned in the Tahquamenon River, but this population has been extirpated (Hay-Chmielewski and Whelan 1997; Holey et al. 2000; Zollweg et al. 2003; Pratt 2008). Baker (2006) located no adult or larval sturgeon during 1996-1999 surveys of the Tahquamenon River.

Lake Michigan



Tributaries of Lake Michigan with former and current lake sturgeon spawning populations

Basin-wide Distribution and Abundance

Historically, the largest population of lake sturgeon in the Great Lakes was that of Lake Michigan, with populations spawning in many of the major tributaries and on some shoal areas in the lake (Hay-Chmielewski and Whelan 1997). Lake sturgeon were historically extremely abundant in Lake Michigan, with many early references describing lake sturgeon as abundant or plentiful (Kinietz 1965; Slade and Auer 1997). Lake sturgeon were particularly abundant in the shallow productive waters of Green Bay and its surrounding tributaries (Elliott and Gundermann 2008). While specific numbers were hard to calculate, many scientists believe that the adult lake sturgeon population in Lake Michigan was more than 1 million fish in the 1800s (Hay-Chmielewski and Whelan 1997). Hay-Chmielewski (1997) estimated that there were 2,406,000 lake sturgeon over 50 pounds in Lake Michigan in 1825; and that the population declined to an estimated 279,000–977,000 adult sturgeon by 1890.

Based on historic accounts before the 19th century, lake sturgeon populations in and around the state of Michigan had a biomass in the tens of millions of pounds (Tody 1974). Haxton et al. (2014) estimated that the biomass of lake sturgeon in Lake Michigan was 18.68 million pounds in 1882. Lake sturgeon were likely past their peak harvest when commercial harvest records were first documented for Lake Michigan, indicating that the estimate by Haxton et al. (2014) is below the real unexploited historical standing stock. Commercial catch records suggest that Lake Michigan may have supported a lake sturgeon population of up to 11 million fish of all ages, lake-wide (Hay-Chmielewski and Whelan 1997).

Despite historically abundant populations, lake sturgeon numbers in Lake Michigan quickly plummeted as commercial fishing of the species increased in the early 1900s. Lake sturgeon went from being classified as a nuisance fish by early settlers, to a commercially desirable fish for production of caviar and smoked sturgeon flesh by the 1860s. In 1879 alone, the first year that records were kept and when the population had already started to decline, 3.8 million pounds of lake sturgeon were harvested from Lake Michigan (Baldwin et al. 1979). By 1928 the annual commercial harvest in Lake Michigan had declined to a mere 2,000 pounds (Baldwin et al. 1979). Lake Michigan populations were estimated in the 1970s to be at most 1% of their former abundance (Tody 1974). By the 1990s the most optimistic estimate of the lake-wide abundance was 5,000-10,000 fish, well below 1% of the most conservative estimates of historic abundance (Hay-Chmielewski and Whelan 1997). Today, only about 3,000 adult lake sturgeon are believed to remain in Lake Michigan (Donofrio and Utrup 2013). Approximately 1,400 spawning age adults are estimated to remain in lower Green Bay (Elliott and Gunderman 2008).

In western Lake Michigan, former lake sturgeon spawning populations have been extirpated from 12 of the 20 tributaries (60%) which supported the species (Sturgeon River, Whitefish River, Escanaba River, Ford River, Kewaunee River, East Twin River, West Twin River, Manitowoc River, Sheboygan River, Barr Creek, Milwaukee River and Root River), as well as from Brevoort Lake. In an additional 5 tributaries (25%) to western Lake Michigan (Millecoquins River, Manistique River, Indian River/Indian Lake, Cedar River and Oconto River), lake sturgeon persist only as very small remnant runs, with no more than 25-50 annual spawners, well below minimum population viability. There are small spawning populations in the Peshtigo River (which has about 200 spawning sturgeon annually) and the Menominee River (with 500-600 spawners in the lower river and landlocked populations upstream). The only significant population left in western Lake Michigan is in the Lake Winnebago system, with about 20,000 adult spawners in the entire system. Welsh et al. (2010) characterized self-sustaining lake sturgeon populations in the Great Lakes as having a minimum of 750 sexually mature fish; in western Lake Michigan only Lake Winnebago meets this criteria.

In eastern Lake Michigan, former lake sturgeon spawning populations have been extirpated from 2 of the 7 tributaries (29%) which supported the species (Galien River and Boardman River), as well as from Wolf Lake. In an additional 5 tributaries (71%) to eastern Lake Michigan (St. Joseph, Kalamazoo River, Grand River, Muskegon River and Manistee River), lake sturgeon persist only as small remnant runs, with no more than 20-100 annual spawners, well below minimum population viability. There are no remaining large populations of lake sturgeon in eastern Lake Michigan.

For the entire Lake Michigan, lake sturgeon populations have been extirpated from 14 of 27 former spawning tributaries (52%), and are at dangerously low population numbers in 10 additional tributaries (37%) (see Holey et al. 2000; Welsh 2004; Schneeberger et al. 2005; Caroffino et al. 2007; Elliott 2008; USEPA 2009; Hayes and Caroffino 2012; Donofrio and Utrup 2013).

Streamside rearing facilities for lake sturgeon have been initiated in 4 tributaries where the species has been extirpated, on the Milwaukee, Manitowoc, Cedar and Whitefish rivers (Baker et al. 2008). A streamside rearing facility is also being used to increase the survival of naturally produced larvae in the Manistee River (Holtgren et al. 2007); a similar rearing facility is proposed for the Muskegon River. Young sturgeon have been stocked in the upper Menominee River and fish passage projects are being pursued for lake sturgeon in the lower Menominee River.

Western Lake Michigan

Brevoort Lake, Michigan

Brevoort Lake (also known as Brevort Lake) is a lagoon on the northern Michigan peninsula. This lake formerly had a landlocked population of lake sturgeon (Baker 1980; Hay-Chmielewski and Whelan 1997).

Millecoquins River, Michigan

The Millecoquins River flows though the Upper Peninsula of Michigan into northwestern Lake Michigan.

Small numbers of lake sturgeon were reported in the Millecoquins River from 1970-1980 below Millecoquins Lake (Baker 1980). Adult lake sturgeon may periodically spawn in the lower Millecoquins (Hay-Chmielewski and Whelan 1997). The spawning run is small and remnant, estimated at less than 10-25 adults annually (Holey et al. 2000; Zollweg et al. 2003; Hayes and Caroffino 2012), well below minimum population viability. Baker (2006) surveyed the Millecoquins River from 1997–1999 for adult and larval lake sturgeon, and only found a single male and female pair observed spawning and captured in April 1998, with no other reported spawning through 2006.

Manistique River, Michigan

The Manistique River rises from the outlet of Manistique Lake (locally called Big Manistique Lake to distinguish it from the other lakes in the Manistique Lakes system), and flows 114 km though the Upper Peninsula of Michigan into northern Lake Michigan.

A small remnant population of lake sturgeon remains in the Manistique River, with presumed spawning runs, but successful spawning has not been documented (Zollweg et al. 2003) and the population is apparently well below minimum population viability (Baker 2006). Population estimates of adult lake sturgeon in the Manistique River were: 200 adult fish > 40 inches (Hay-Chmielewski and Whelan 1997); 10s of spawners (Holey et al. 2000; Zollweg et al. 2003); less than 25 spawners (Auer et al. 2004); less than 10 spawners (Daugherty et al. 2009); and less than 25 adults (Hayes and Caroffino 2012).

Baker (2006) captured only 2 lake sturgeon during gill-net and setline sampling in the Manistique River mouth below the Manistique Paper Mill Dam from 1996-2000 and 2003-2005. Both fish were ripe males in spawning condition, indicating spawning may have been taking place below the dam, however no eggs were observed and no larvae or juvenile fish were captured in the Manistique River. Lake sturgeon were also known to be present above the dam and it is possible the fish captured below the dam were produced upstream and moved downstream over the dam; it is also possible that the fish came from Indian Lake, which is connected to the Manistique River via the Indian River just upstream of the Manistique Dam.

Manistique Lake

Baker (1980) noted that a landlocked population of lake sturgeon persisted in Manistique Lake. There are currently thought to be less than 25 adult fish in Big Manistique Lake, well below minimum population viability (Hayes and Caroffino 2012; Donofrio et al. 2014).

Indian River/Indian Lake

Indian Lake feeds into the Indian River, which is a tributary of the Manistique River.

Prior to construction of dams on the Manistique River and the Indian River downstream from Indian Lake, the Indian Lake population had access to Lake Michigan (Galarowicz 2003). Baker (1980) noted a small landlocked population of lake sturgeon in Indian Lake, which spawned in the upper reaches of the Indian River. Lake sturgeon in Indian Lake could move downstream to Lake Michigan but could not return beyond the lower dam on the Manistique River (Bassett 1981). Bassett (1981) captured ripe male and female lake sturgeon in Indian River, and Bassett (1991) returned a decade later and captured 15 lake sturgeon during gill-net sampling in Indian Lake, but was unable to calculate a population estimate because no fish were recaptured.

Zollweg et al. (2003) noted that Indian River/Lake had a remnant lake sturgeon run, but that it was unknown if there was any spawning. During surveys from 1996–1999 and in 2004, Baker (2006) captured only 6 lake sturgeon (from 104-165 cm TL) in Indian Lake, and no sturgeon from 1996-1999 in the Indian River. Baker (2006) found lake sturgeon of sizes indicating that natural reproduction had occurred since Bassett's 1991 effort, but no spawning activity had been documented since 1981 and there were no data suggesting the Indian Lake population was reproducing or self-sustaining. Baker (2006) was unable to document spawning in Indian River by either visual survey or larval drift netting, and sampling for juvenile lake sturgeon was unsuccessful. Baker (2006) concluded that the Indian Lake population is small and may be declining. Hayes and Caroffino (2012) estimated only 60 adult lake sturgeon remain in Indian Lake.

Sturgeon River (Nahma), Delta County, Michigan

The Sturgeon (or Nahma) River in Delta County, Michigan flows through the Upper Peninsula of Michigan into Big Bay de Noc in Green Bay.

Lake sturgeon formerly spawned in the Sturgeon River (Holey et al. 2000; Galarowicz 2003), but the population has been extirpated (Holey et al. 2000). Baker (2006) sampled the Sturgeon River in 1996 and from 2003-2005 for adult and larval lake sturgeon, but was unable to locate any sturgeon.

Whitefish River, Michigan

The Whitefish River also flows through the Upper Peninsula of Michigan into Big Bay de Noc in Green Bay.

Lake sturgeon formerly spawned in the Whitefish River (Hay-Chmielewski and Whelan 1997; Holey et al. 2000; Galarowicz 2003; Zollweg et al. 2003), but the population has been extirpated (Holey et al. 2000; Zollweg et al. 2003). Baker (2006) sampled the Whitefish River in 1996 and from 2003-2005 for adult and larval lake sturgeon, but was unable to locate any sturgeon.

A streamside rearing facility for lake sturgeon was initiated on the Whitefish River in 2006 (Baker et al. 2008), using Menominee River sturgeon, with the stocking decision based on genetic data by DeHaan et al. (2006).

Escanaba River, Michigan

The Escanaba River flows through the Upper Peninsula of Michigan into Little Bay de Noc in Green Bay.

Lake sturgeon formerly spawned in the Escanaba River (Hay-Chmielewski and Whelan 1997; Holey et al. 2000; Zollweg et al. 2003), but the population has been extirpated (Holey et al. 2000; Zollweg et al. 2003). Baker (2006) sampled the Escanaba River in 1996 and from 2003-2005 for adult lake sturgeon, but was unable to locate any sturgeon.

Ford River, Michigan

The Ford River is a tributary of Lake Michigan that flows into Green Bay.

Lake sturgeon formerly spawned in the Ford River (Hay-Chmielewski and Whelan 1997). Baker (2006) sampled the Ford River from 1998-1999 for larval lake sturgeon, but did not locate any sturgeon. Daugherty et al. (2008) found that the Ford River still contains high quality potential spawning habitat for lake sturgeon, but lacks suitable staging habitats for sturgeon adjacent to suitable spawning areas.

Cedar River, Michigan

The Cedar River flows into Lake Michigan via Green Bay.

Zollweg et al. (2003) noted that the population status of lake sturgeon in the Cedar River was unknown. Baker (2006) surveyed the Cedar River in 1997 and again from 2003-2005 for adult and larval lake sturgeon, but failed to detect any sturgeon. A single tagged lake sturgeon was recovered at the mouth of the Cedar River in 2005 (Baker 2006). Hayes and Caroffino (2012) estimated there are less than 25 adult lake sturgeon in the Cedar River population, far below minimum population viability.

A streamside rearing facility for lake sturgeon was initiated on the Cedar River in 2006 (Baker et al. 2008), using Menominee River sturgeon, with the stocking decision based on genetic data by DeHaan et al. (2006).

Menominee River, Wisconsin/Michigan

The Menominee River, which forms part of the boundary between Michigan and Wisconsin, flows into Lake Michigan via Green Bay.

The Menominee River historically supported one of the largest annual spawning runs of lake sturgeon in Lake Michigan and contained extensive rearing areas for sturgeon; lake sturgeon were able to migrate up 125 km of river to the base of Sturgeon Falls (Thuemler 1997; Baker 2006; Donofrio and Utrup 2013). The historic lake sturgeon population in the Menominee River is estimated to have been 20,000 to 25,000 fish (Donofrio and Utrup 2013).

There are now 11 hydroelectric dams on the river which prevent lake sturgeon in Lake Michigan from migrating up the river to get to prime spawning and rearing habitat (Donofrio and Utrup 2013), including the Menominee, Park Mill, Grand Rapids, White Rapids and Chalk Hill hydroelectric dams (Coscarelli et al. 2011). Lake sturgeon currently can only migrate less than 4 km upstream from Lake Michigan, where passage is blocked by the Upper Scott Paper Company Dam, built in 1924 at the base of a high gradient stretch of river (Auer 1996a; Thuemler 1997; Donofrio and Utrup 2013).

Two landlocked upstream lake sturgeon populations persist in the Menominee River, between White Rapids Dam (river km 81) and Grand Rapids Dam (river km 42), and Grand Rapids Dam to Scott Impoundment (Priegel 1973; Thuemler 1997; WDNR 2012). These populations are fragmented and isolated from Green Bay and each other by the dams (Baker 1980; Hayes and Caroffino 2012). Some downstream movement of sturgeon from these upper river sections into lower sections of the river has been documented (Elliott and Gunderman 2008), but these fish cannot return upstream beyond the first dam. Limited habitat availability, water quality issues, and erratic flows from hydropower dam operations limit the growth of these landlocked populations (Auer 1996a; Donofrio and Utrup 2013). More than 70% of the high-gradient habitat once used by lake sturgeon in the Menominee River is now impounded (Thuemler and Schnicke 1992). Daugherty et al. (2009) determined that only 6.4 km (10%) of the 64 km of high quality spawning habitat in various reaches of the Menominee River is available to lake sturgeon; 90% is blocked by dams and only 3 km (4%) of the river’s age-0 juvenile habitat is available to lake sturgeon.

Priegel (1973) estimated the population of adult lake sturgeon (42 inches and larger) between White Rapids and Grand Rapids dams to be 185-234 fish from 1969-1970. Thuemler (1997) estimated a resident summer lake sturgeon population of 457-1,329 fish in 1991. Hay-Chmielewski and Whelan (1997) estimated a total lake sturgeon population of 7,250 sub-adult and adult fish in all river segments. From 1996–2005 Baker (2006) captured 465 lake sturgeon (from 50–171 cm TL) in the lower Menominee River, with confirmed spawning and a population that appeared to be self-sustaining. Zollweg et al. (2003) estimated an annual spawning run of 500 spawners in all river segments; Elliott and Gunderman (2008) estimated 340 annual spawners in all river segments. Hayes and Caroffino (2012) estimated a large stable population of 5,272 adult sturgeon in all river segments. It is thought that the current spawning migration in the lower Menominee River is 500-600 lake sturgeon adults (>50 inches) annually (Donofrio and Utrup 2013; Donofrio et al. 2014). The current landlocked sturgeon population above the lower two dams is thought to be about 1,100 adults (Donofrio and Utrup 2013).

Young sturgeon have been stocked into the upstream river section below Sturgeon Falls for several years (WDNR 2012). State agencies are pursuing fish passage projects for lake sturgeon, including through a FERC relicensing process, at the lower two dams on the Menominee River (GLRI 2010; Donofrio and Utrup 2013; Kampa et al. 2014a). A bypass will enable downstream-moving sturgeon to get through the upper dam, and an elevator fish lift at the lower dam will help move lake sturgeon upstream. The long-term fish passage goal is to provide passage for lake sturgeon at five hydropower dams on the Menominee River by 2020 (GLRI 2010).

Peshtigo River, Wisconsin

The Peshtigo River flows into Lake Michigan via Green Bay.

Historically, lake sturgeon were known to be distributed throughout the lower 67 km of the Peshtigo River (Daugherty et al. 2009), and may have migrated as far upstream as Johnson Falls at river km 96 (FERC 1996). Lake sturgeon access to historic spawning grounds in the Peshtigo River is blocked by Peshtigo Dam and migrations now are limited to the 12 km stretch of river above Green Bay and below Peshtigo Dam (Auer 1996a; Elliott and Gunderman 2008). Daugherty et al. (2009) determined that 97% of the high quality spawning habitat for lake sturgeon in the Peshtigo River is blocked by the Peshtigo and Potato Rapids dams. Juvenile lake sturgeon in the Peshtigo River historically had 60 river km or more to use as nursery habitat but now have access to less than one-third of this amount (Caroffino et al. 2010b).

The annual lake sturgeon spawning population in the lower Peshtigo River is small, variously estimated at 200 adults (Holey et al. 2000); less than 200 spawners (Zollweg et al. 2003); 199-577 adults, with a high proportion of younger individuals (Gunderman and Elliott 2004); 100-200 fish from 1998-2000 (Holey and Trudeau 2005); 200 or more fish from 2002-2006 (Elliott and Gunderman 2008); and 200 fish (Donofrio et al. 2014). Lake sturgeon spawning in the lower Peshtigo River is limited to a very small area, with egg deposition and incubation occurring only in the first 50 m below the Peshtigo Dam (Caroffino 2009). DeHaan et al. (2006) believed that migration may occur between the Peshtigo River and the nearby Oconto River, increasing spawning opportunities. Documented high rates of predation by invasive crayfish and upstream invasion of round goby pose a threat to sturgeon eggs, larvae and age-0 juveniles in the lower river (Caroffino et al. 2010a).

Oconto River, Wisconsin

The Oconto River flows into Lake Michigan in northeastern Wisconsin via Green Bay.

The Stiles, Lower Oconto Falls, and Upper Oconto Falls hydroelectric dams block historical lake sturgeon spawning or nursery habitat (Coscarelli et al. 2011). The historic natural barrier to upstream migration of lake sturgeon in the Oconto River was possibly Oconto Falls at river km 32 (Elliott and Gunderman 2008). Lake sturgeon access from Lake Michigan to historic spawning grounds in the Oconto River is now blocked by Oconto Falls Dam, 6 km upstream from Lake Michigan (Auer 1996a). No lake sturgeon now exist upstream of Stiles Dam at river km 22 (Elliott and Gunderman 2008). Daugherty et al. (2009) determined that 89% of the high quality spawning habitat for lake sturgeon in the Oconto River is blocked by Stiles Dam.

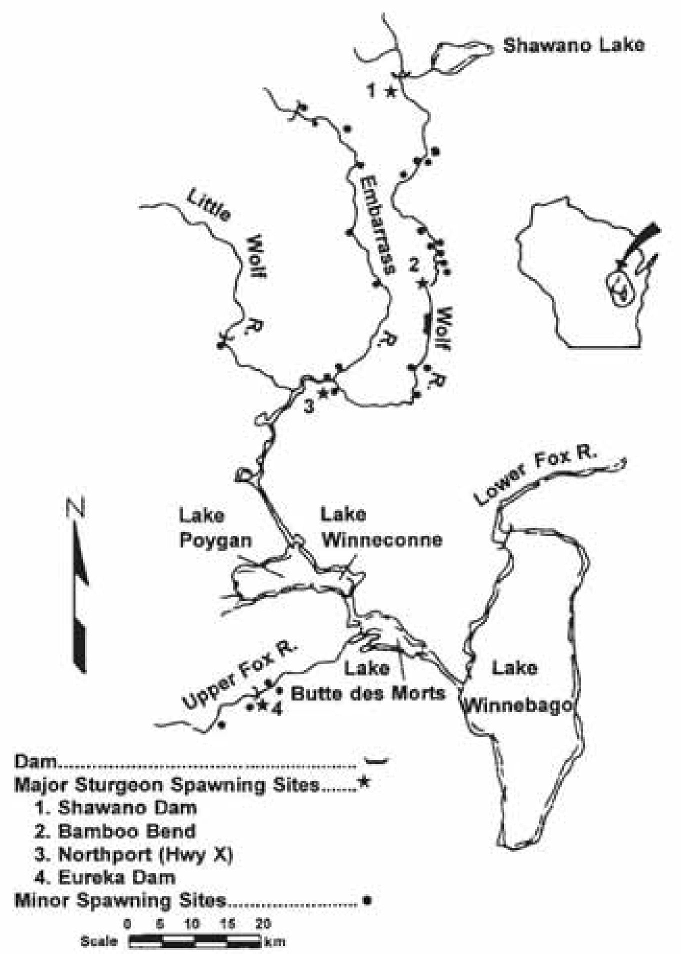
The Oconto River currently has a very small remnant lake sturgeon population (Holey et al. 2000), thought to be less than 25-50 spawners annually (Zollweg et al. 2003 Elliott and Gunderman 2008; Donofrio et al. 2014). Only a small proportion of spawning lake sturgeon in the lower Oconto are more than 20 years old (Gunderman and Elliott 2004).

Lake Winnebago System, Wisconsin

The Winnebago system is a riverine-lake system in east-central Wisconsin. Three upriver lakes known as the Winnebago Pool Lakes include Lake Winnebago, Lake Butte des Morts and Lake Poygan. The Winnebago Pool Lakes are at the lower end of a watershed through which the Wolf and upper Fox rivers flow. Lake Winnebago is drained by the lower Fox River which flows north into Green Bay in western Lake Michigan, but the Fox River has to flow through 14 locks and 17 dams before reaching Lake Michigan.

The Winnebago system supports one of the largest remaining self-sustaining stocks of lake sturgeon, with an estimated spawning population of about 20,000 adult fish in the entire system (Donofrio et al. 2014). There is no evidence stocking has ever occurred in this system (Bruch 1999). The spawning and nursery areas for lake sturgeon in the Winnebago system are the lower 200 km of the Wolf River, along with its tributaries, and 60 km of the upper Fox River (Bruch 1999). Juvenile sturgeon from nursery areas in the upriver lakes gradually work their way down to Lake Winnebago (Bruch 1999). The downstream movement of Lake Winnebago sturgeon into the lower Fox River has been observed (Bruch 1999).

Early concerns about overfishing led to successively stricter sturgeon harvest regulations, beginning with implementation of minimum size limits in 1903, a ban on all sturgeon harvest from 1915 through 1931, closing of a set-line fishery in 1952, and shortening seasons, reducing bag limits, and increasing minimum size limits through the 1990s (Bruch 1999). Tightened fishing regulations led to an increase in the lake sturgeon population density in the Winnebago system over four decades, with population estimates of 11,500 sturgeon >102 cm in 1959 (Priegel and Wirth 1975; WDNR 1975); 25,300 sturgeon >114 cm in 1980 (Folz and Meyers 1985); 46,500 sturgeon >114 cm in 1989 (Bruch 1999); and 51,691 adult sturgeon in 1995 (Bruch 1999). However, harvest trends showed a steady decline in large-sized sturgeon beginning in the early 1970s with a precipitous decline from the mid 1980s, along with declines in the relative numbers of larger, older fish (Bruch 1999). The nearly complete lack of female fish older than 50 years or males older than 40 years in the population in the 1990s demonstrated an apparent overexploitation of adult females by fisheries (Bruch 1999).



Map of Lake Winnebago system (from Bruch and Binkowski 2002)

Fox River

The Fox River is the largest tributary to Green Bay. The Upper Fox River flows from central Wisconsin through Lake Butte des Morts into Lake Winnebago, and the lower Fox River links Lake Winnebago to Lake Michigan, via Green Bay.

Lake sturgeon were historically abundant in the lower Fox River, but declined in this river reach in the late 1800s (DeHaan et al. 2006). Daugherty et al. (2009) determined that 84% of the high quality spawning habitat for lake sturgeon in the lower Fox River is blocked by the Rapide Croche Dam and Lower Kaukauna Dam. De Pere hydroelectric dam also blocks historical lake sturgeon spawning or nursery habitat (Coscarelli et al. 2011). Lake sturgeon access to historic spawning grounds in the upper Fox River has been blocked by 14 locks and 17 dams (Auer 1996a).

The Fox River currently has a very small reproducing population of lake sturgeon, with spawning below the lowest dam, as well as in the upper river as far upstream as Lake Puckaway (Holey et al. 2000; Zollweg et al. 2003; WDNR 2012). Recent spawning population estimates for the lower Fox River have ranged from 30-100 fish (Zollweg et al. 2003; Gunderman and Elliott 2004; Holey and Trudeau 2005; Elliott and Gunderman 2008; Daugherty et al. 2009; Donofrio et al. 2014). Gunderman and Elliott (2004) noted that legacy PCBs and predation by common carp may limit recruitment in this population. The upper Fox River also has a remnant lake sturgeon population, with an estimate of 200-300 annual spawners (Zollweg et al. 2003).

Some stocking of lake sturgeon occurred in the upper Fox River at Princeton in 2002 (DTO 2002).

Wolf River

The Wolf River is a tributary of the Fox River.

Lake sturgeon historically migrated up the Wolf River to spawn at Keshena Falls, which was blocked by construction of two dams downstream in the late nineteenth and early twentieth centuries (Runstrom et al. 2002). The Shawano and Balsam Row hydroelectric dams block historical lake sturgeon spawning or nursery habitat (Coscarelli et al. 2011). Spawning now occurs upstream to Shawano (WDNR 2012), but lake sturgeon are extirpated from above Keshena (Zollweg et al. 2013). Becker (1983) noted that the lake sturgeon was “common” in the lower Wolf River.

The lower Winnebago-Wolf River system currently has a large lake sturgeon population, estimated at 22,000 fish (Holey et al. 2000; Zollweg et al. 2003).

Lake sturgeon have been stocked since 1994 in lakes on the Menominee Indian Reservation (Runstrom et al. 2002). Transfer of lake sturgeon from the lower Wolf River to several reaches of the Wolf River on the reservation (Keshena Falls 10 km upstream of Balsam Row Dam; Big Eddy Falls 20 km above the dam; and the Dalles 32 km above the dam) resulted in enough adults present in reservation waters in the spring of 2001 that spawning may have occurred in this reach of river for the first time in over 50 years (Runstrom et al. 2002).

Lake Poygan

Preigel and Wirth (1978) estimated a population of 5,202 lake sturgeon over 40 inches in Lake Poygan (and connected Lake Winneconne) in 1955. This population had declined to an estimated 3,730 fish by 1957 due to overharvest. Some recovery likely occurred due to fishing restrictions, since Becker (1983) noted that lake sturgeon were "common" in Lake Poygan. It has been determined that little intermixing occurs between lake sturgeon from Lake Winnebago and Lake Poygan (Preigel and Wirth 1978; Lyons and Kempinger 1992).

Kewaunee River, Wisconsin

The Kewaunee River flows through eastern Wisconsin into western Lake Michigan.

A former lake sturgeon spawning population in the Kewaunee River has been extirpated (Holey et al. 2000; Zollweg et al. 2003).

East/West Twin Rivers, Wisconsin

The East Twin and West Twin rivers flow through eastern Wisconsin into western Lake Michigan.

Former lake sturgeon spawning populations in the East Twin and West Twin rivers have been extirpated (Holey et al. 2000; Zollweg et al. 2003).

Manitowoc River, Wisconsin

The Manitowoc River flows through eastern Wisconsin into western Lake Michigan.

A former lake sturgeon spawning population in the Manitowoc River has been extirpated (Zollweg et al. 2003).

A streamside rearing facility for lake sturgeon was installed in 2006 on the Manitowoc River (MHTR 2007; Baker et al. 2008), using Lake Winnebago sturgeon, with the stocking decision based on genetic data by DeHaan et al. (2006). The facility rears lake sturgeon from Lake Winnebago stock to a size of approximately 6 inches for stocking on an annual basis in the river (Baker et al. 2008).

Sheboygan River, Wisconsin

The Sheboygan River flows through eastern Wisconsin into western Lake Michigan.

A former lake sturgeon spawning population in the Sheboygan River has been extirpated (Holey et al. 2000; Zollweg et al. 2003).

Barr Creek, Wisconsin

Barr Creek flows through eastern Wisconsin into western Lake Michigan.

A former lake sturgeon spawning population in Barr Creek has been extirpated (Holey et al. 2000; Zollweg et al. 2003).

Milwaukee River, Wisconsin

The Milwaukee River drains into western Lake Michigan.

Lake sturgeon spawned in the Milwaukee River in the 1800s, but by 1850 a dam built about 5 miles upstream from Lake Michigan prevented adult sturgeon from making it upstream to their spawning grounds (Brunner and Alexander 2013). The former lake sturgeon spawning population in the Milwaukee River has been extirpated (Holey et al. 2000; Zollweg et al. 2003).

A streamside rearing facility for lake sturgeon was initiated in 2003 on the Milwaukee River (Baker et al. 2008; Brunner and Alexander 2013), using Lake Winnebago sturgeon, with the stocking decision based on genetic data by DeHaan et al. (2006). The facility rears lake sturgeon from Lake Winnebago stock to a size of approximately 6 inches for stocking on an annual basis in the Milwaukee River (Baker et al. 2008). The program has stocked 7,400 fingerling sturgeon into the Milwaukee River (Brunner and Alexander 2013).

Root River, Wisconsin

The Root River flows through southeastern Wisconsin into western Lake Michigan.

A former lake sturgeon spawning population in the Root River has been extirpated (Holey et al. 2000; Zollweg et al. 2003).

Eastern Lake Michigan

Galien River, Michigan

The Galien River is a southeastern tributary of Lake Michigan.

Lake sturgeon used to occur in the Galien River (Hay-Chmielewski and Whelan 1997), but appear to be extirpated.

St. Joseph River, Michigan/Indiana

The St. Joseph River is an eastern tributary to Lake Michigan that flows through southwestern Michigan and northeastern Indiana. It is the third largest river basin in Michigan, with a mainstem 210 miles long and an additional 1,641 miles of tributary streams (Brown 1944; Wesley and Duffy 1999).

Natural history reports and archaeological investigations in the area confirm that lake sturgeon were historically present in the St. Joseph River (Holman et al. 1996; Wesley and Duffy 1999). Ballard (1948) reported that the St. Joseph River was “thick” with lake sturgeon migrating upstream to spawn. The area around Niles was famous for lake sturgeon in the mid- to late-1800s, with lake sturgeon up to 300 pounds reported to have been commonly caught (Ballard 1948; Wesley and Duffy 1999).

Before construction of dams on the St. Joseph River, lake sturgeon had access to suitable spawning habitat as far up river as Hillsdale County, at river km 286; they are now limited to spawning in the river immediately below Berrien Springs Dam at river km 37, which blocks upstream migration into historic habitat (Auer 1996a; Wesley and Duffy 1999; Coscarelli et al. 2011). After dam construction, the lake sturgeon population declined dramatically in the St. Joseph River (Wesley and Duffy 1999).

Small numbers of lake sturgeon were reported in the St. Joseph River from 1970-1980 below Berrien Springs Dam (Baker 1980). A few individual sturgeon were observed ascending fish ladders in the lower segment of the St. Joseph River in 1994 (Wesley and Duffy 1999). A lake sturgeon population may possibly survive upstream of the lower dam on the St. Joseph River (Daugherty and Sutton 2004), where fish would be able to move downstream to Lake Michigan but not return upstream beyond the first dam.

Adults are thought to periodically spawn in the lower St. Joseph River (Hay-Chmielewski and Whelan 1997), the only spawning population of lake sturgeon in Indiana from Lake

Michigan (GLLSCM 2002; Welsh 2004). The current population status is unknown but is thought to be small (Holey et al. 2000; Zollweg et al. 2003). The spawning population in the lower river is estimated to be less than 25 adult lake sturgeon (Hayes and Caroffino 2012; Donofrio et al. 2014).

Kalamazoo River, Michigan

The Kalamazoo River is an eastern tributary to Lake Michigan.

A remnant lake sturgeon population in the Kalamazoo River is of unknown size but is thought to be small (Holey et al. 2000), with less than 20-42 sturgeon spawning annually (Daugherty and Sutton 2004; Hayes and Caroffino 2012; Donofrio et al. 2014).

The Allegan hydroelectric dam blocks historical lake sturgeon spawning or nursery habitat in the Kalamazoo River (Coscarelli et al. 2011).

Grand River, Michigan

The Grand River is an eastern tributary to Lake Michigan.

Lake sturgeon historically had access to spawning habitat in the Grand River up to Grand Rapids at river km 64 upstream from Lake Michigan (Auer 1996a).

Small numbers of lake sturgeon were reported in the Grand River from 1970-1980 below the city of Grand Rapids (Baker 1980). A remnant lake sturgeon population is of unknown size but is thought to be small (Holey et al. 2000; Zollweg et al. 2003), with a declining population estimated at 103 adults (Hayes and Caroffino 2012) and an annual spawning run of less than 25 fish (Elliott 2008) or up to 66 fish (Donofrio et al. 2014).

Muskegon River, Michigan

The Muskegon River is an eastern tributary to Lake Michigan.

A major commercial sturgeon fishery was operating out of the Muskegon River by 1885 (Bogue 2000), suggesting that the Muskegon River once supported one of the larger lake sturgeon populations in eastern Lake Michigan. Severe declines of lake sturgeon have occurred in the Muskegon River (O'Neal 1997). The construction of Newaygo Dam in 1900 blocked upstream passage of lake sturgeon to the only high gradient portions of the Muskegon River with suitable spawning habitat (Peterson and Vecsei 2004). Although Newaygo Dam was demolished in 1968, upstream migration continues to be blocked by Croton Dam, 67 km upstream from Lake Michigan (Auer 1996a; Wieten 2013). Both Croton and Hardy hydroelectric dams block historical lake sturgeon spawning or nursery habitat (Coscarelli et al. 2011). Small numbers of lake sturgeon were reported in the Muskegon River from 1970-1980 below Croton Dam and also in Muskegon Lake (Baker 1980).

Currently, the section of river between the former Newaygo Dam and Croton Dam is the only suitable spawning habitat for lake sturgeon (Scott and Crossman 1983; O'Neal 1997; Wieten 2013). The remnant lake sturgeon population is thought to be small (Holey et al. 2000), with recent estimates of annual adult spawners at less than 25 fish (Zollweg et al. 2003); 15-24 fish (Peterson and Vecsei 2004); 39-46 fish (Wieten 2013); 40-60 fish

(Meyerson 2013); and 60-100 fish (Donofrio et al. 2014). Wieten (2013) confirmed reproduction by capture of 16 larval lake sturgeon in 2010 and 2 individuals in 2011.

Harris et al. (2017) estimated that the number of spawners each year was low (probably <50 individuals in most years) and noted that recovery of this remnant population is uncertain given the population age structure and low rate of adult recruitment found during their study. Harris et al. (2017) captured lake sturgeon in Muskegon Lake (which connects the Muskegon River to Lake Michigan) from 2008–2013 using gill nets and captured adults with boat electrofishing in the Muskegon River. A total of 268 unique lake sturgeon were captured and 180 fish were aged using pectoral fin rays, representing 27 age cohorts and a mean age of 7.6 years.

The Michigan DNR is planning to initiate a streamside sturgeon rearing station on the Muskegon River, which will collect drifting sturgeon eggs and larvae in the spring, rear them, and release them back to the river in the fall; with a goal of restoring a minimum population of 300 adults (Meyerson 2013).

Wolf Lake, Michigan

A former isolated lake sturgeon population in Wolf Lake, Michigan has been extirpated (Holey et al. 2000).

Manistee River, Michigan

The Manistee River is a tributary to eastern Lake Michigan. Manistee Lake is located 3 km upstream from Lake Michigan and is formed by the confluence of the Big and Little Manistee rivers.

Lake sturgeon were most likely “very abundant” in the Manistee River prior to European settlement (Tonello 2004). The Big Manistee River lake sturgeon population is believed to have historically been one of the largest in the Lake Michigan basin (Hay-Chmielewski and Whelan 1997; LRBOI 2008).

Tippy Dam, a large hydroelectric facility completed in 1918 and located 45 km upstream from Lake Michigan, blocks lake sturgeon migration into historic spawning grounds (Auer 1996; Coscarelli et al. 2011), as does Hodenpyl hydroelectric dam (Coscarelli et al. 2011). Small numbers of lake sturgeon were reported in the Manistee River from 1970-1980 below Tippy Dam (Baker 1980). Lake sturgeon were known to have occurred historically in the Pine River tributary (Hay-Chmielewski and Whelan 1997).

A small remnant lake sturgeon population inhabits the reach from the mouth of the Manistee River to Tippy Dam, with the annual spawning population estimated at less than 50 fish (Holey et al. 2000; Gunderman 2001; Peterson et al. 2002; Lallaman 2003; Zollweg et al. 2003); or more recently 21-66 fish (Lallaman et al. 2008; Donofrio et al. 2014). Baker (2006) surveyed the Manistee River in 1997 and located only 6 adult sturgeon (154–180 cm TL). Baker (2006) noted that the Little River Band of Ottawa Indians confirmed that lake sturgeon larvae were produced in the Manistee River and that older young of the year fish had also been captured; but because of the small number of spawning adults there is concern about the long-term viability of the population. Hayes and Caroffino (2012) thought there is a stable lake sturgeon population of 400 adult fish (not all of which spawn annually) in the Manistee River.

Since 2004, the Little River Band of Ottawa Indians has operated a streamside rearing facility on the Big Manistee River to increase the survival of naturally produced lake sturgeon larvae, with stocking of fingerling lake sturgeon raised from larvae collected and reared in the Big Manistee River (Holtgren et al. 2007; LRBOI 2008). The restoration target is 750 adult fish (LRBOI 2008).

Grand Traverse Tributaries, Michigan

Lake sturgeon formerly occurred in the Boardman River, Torch Lake and Elk Lake, tributaries to Grand Traverse Bay in northeastern Lake Michigan (Hay-Chmielewski and Whelan 1997). Lake sturgeon are now extirpated from the Boardman River (Zollweg et al. 2003).

Michigan Inland Lakes

Lake sturgeon have been introduced to several inland lakes in Michigan where they were not native.

A put-and-take lake sturgeon population was created in Otsego Lake through stocking experiments, to provide sturgeon fishing opportunities regardless of the lake's sturgeon population size. Hayes and Caroffino (2012) estimated a small stable population of 100 adult lake sturgeon in Ostego Lake. Ostego Lake was stocked with hatchery lake sturgeon from the Black River in 2013 (Engle 2013). The lake currently has a population of unknown size (LHLSWG 2017).

Lake sturgeon populations are declining in other inland lakes (MDNR 2005). Lake sturgeon formerly occurred in Pere Marquette Lake and Portage Lake, on the eastern shore of Lake Michigan (Hay-Chmielewski and Whelan 1997).

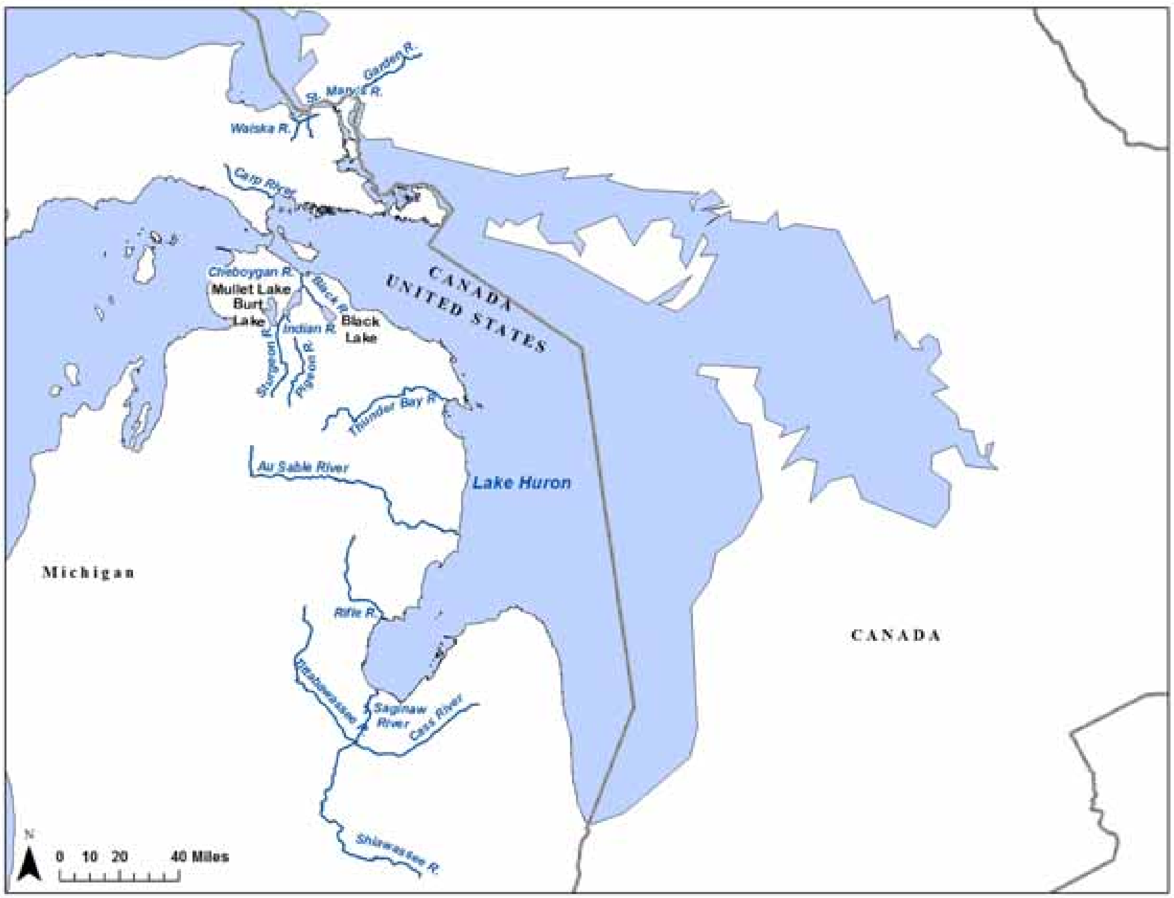
Lake Huron

Basin-wide Distribution and Abundance

Lake sturgeon were historically extremely abundant in Lake Huron: Hay-Chmielewski (1997) estimated that there were 319,000 lake sturgeon over 50 pounds in Lake Huron in 1840; the population declined to an estimated 170,000-224,000 adult sturgeon by 1885. Haxton et al. (2014) estimated that the biomass of lake sturgeon in Lake Huron was 16.73 million pounds in 1879.

At least 34 tributaries of Lake Huron in the U.S. and Canada historically supported spawning populations of lake sturgeon (Zollweg et al. 2003).

There were at least 15 tributaries and lakes on the U.S. side of Lake Huron with former spawning populations of lake sturgeon. Pratt (2008) identified lake sturgeon populations in 12 U.S. tributaries of Lake Huron, but Hayes and Caroffino (2012) identified only 9, with 5 of those well below minimum viable population levels (less than 25 adult lake sturgeon) and 4 populations considered "stable." Many former spawning populations in tributaries on the U.S. side have been extirpated (Au Sable, Cass, Saginaw, Shiawassee, Thunder Bay, Tittabawassee and Waiska rivers), or are thought to have very small remnant populations that are near extirpation (Black, Carp, Cheboygan, Indian, Pigeon, Rifle, Sturgeon and St. Marys rivers, and Burt and Mullet lakes). The exception is the population in Black Lake, which was nearly extirpated but has been rebuilt as a result of intensive stocking efforts (Chalupnicki et al. 2011). Lake sturgeon restoration stockings have also occurred in Burt Lake and Mullet Lake. Current lake surgeon numbers in Lake Huron and its tributaries remain far below historic levels (USEPA 2009).



U.S. tributaries of Lake Huron with former and current lake sturgeon spawning populations

In the Canadian portion of Lake Huron, lake sturgeon have been extirpated from 13 of 21 historically known sites (62%), and were still extant at 8 sites (Holey et al. 2000), though all of the extant populations were considered small (Hay-Chmielewski and Whelan 1997; Holey et al. 2000; Zollweg et al. 2003; COSEWIC 2006). Successful reproduction of lake sturgeon was only known at 4 Canadian sites, and unknown for the rest (COSEWIC 2006). The size of remaining spawning runs was unknown except for the Mississagi River, where an estimate of the annual spawning run was only on the order of 150 fish (Holey et al. 2000; COSEWIC 2006). The Lake Huron Lake Sturgeon Working Group more recently reported that lake sturgeon are still extant in 14 Canadian rivers tributary to Lake Huron, have been extirpated from 6 Canadian tributaries, and the status is unknown for 6 more tributaries (LHLSWG 2017).

St. Marys River, Michigan

The St. Marys River is the sole outflow of Lake Superior, draining into Lake Huron.

Archeological evidence from St. Marys Rapids indicates that lake sturgeon were an important food for native peoples as long as 5,000 years ago (Duffy et al. 1987). Historically, the St. Marys River was inhabited by spawning lake sturgeon but the population declined dramatically in the 1900s due to overharvest and habitat alteration (Hay-Chmielewski and Whelan 1997; Bauman et al. 2011; Gerig et al. 2011).

Kauss (1991) noted that St. Marys Rapids provided spawning habitat for lake sturgeon. Holey et al. (2000) and Zollweg et al. (2003) noted a small remnant lake sturgeon population of unknown size in the St. Marys River. However it is unclear if lake sturgeon are using the St. Marys River system for spawning or if the fish are staging there prior to traveling up adjacent tributaries to spawn (Elliott et al. 2008). Bauman et al. (2011) captured 192 unique subadult and adult lake sturgeon in the St. Marys River from 2000 to 2007, and estimated the population size at 505 sub-adult and adult sturgeon, with approximately 30% being immatures younger than breeding age; the mean age of sturgeon captured was 20 years (range 7–59 years) and 36 age classes were represented. It was unclear if this represented a self-sustaining population reproducing in the river (Bauman et al. 2011).

Gerig et al. (2011) noted that the Soo Locks, Edison Sault hydroelectric canal, and the St. Marys Rapids compensating works form a barrier that likely limits the movement of lake sturgeon between the upper and lower St. Marys River. Telemetry monitoring of the remnant population of lake sturgeon in the St. Marys River since 2000 indicates that lake sturgeon inhabit a 40 km river reach, representing approximately one-third of the total area of the St. Marys River; movement was confined to an area between the North Channel of Sugar Island to the southern end of East Neebish Island, with the majority centered around the north end of Lake George (Gerig et al. 2011). Within this reach, lake sturgeon have access to tributary rivers and mainstem areas that would provide suitable spawning habitat; anecdotal evidence suggested that the East Neebish Island rapids may be an active lake sturgeon spawning site (Gerig et al. 2011). However, telemetry results to date had not confirmed spawning of lake sturgeon within the St. Marys River, although two females with partially mature eggs were tagged in 2007 (Gerig et al. 2011). Hayes and Caroffino (2012) estimated a medium, stable population of 354 adult sturgeon (not spawners) in the St. Marys River.

Thirty-nine adult lake sturgeon were captured in the lower reaches of the Garden River tributary to the St Mary's River, and implanted with acoustic telemetry transmitter tags (LHLSWG 2017). Receivers in the Garden River recorded 2 sturgeon migrating upriver to suspected spawning locations, one in spring 2016 and one in spring 2017. Following the spawn, larval lake sturgeon were captured at four locations along the Garden River; 85 larvae in 2016 and 243 larvae in 2017, confirming that the Garden River is a spawning tributary for lake sturgeon in the St. Mary's River system (LHLSWG 2017).

Waiska River, Michigan

Small numbers of lake sturgeon were reported in the Waiska River tributary of the St. Marys River from 1970-1980 (Baker 1980).

Carp River, Michigan

The Carp River flows through Mackinaw County, Michigan into northwestern Lake Huron.

Historically, lake sturgeon spawned in the Carp River (Hay-Chmielewski and Whelan 1997; Galarowicz 2008) and suitable spawning habitat still exists (Galarowicz 2008).

Holey et al. (2000) and Zollweg et al. (2003) believed a small, remnant lake sturgeon population of unknown size persisted in the Carp River, but Baker (2006) surveyed the Carp River from 1996-1998 for adult and larval lake sturgeon but did not locate any sturgeon. Baker (2006) noted that adult lake sturgeon were known to be present in the spring in the Carp River, but with no evidence of spawning or data suggesting that this population was reproducing or self-sustaining. Hayes and Caroffino (2012) estimated a small population of less than 25 adult fish in the Carp River, well below minimum population viability. The run is currently considered to be extant, with occasional observations of spawning, and the annual spawning run size unknown (LHLSWG 2017).

Cheboygan River System, Michigan

The Cheboygan River flows from Mullet Lake into Lake Huron. The largest tributary of the Cheboygan is the Black River, which drains Black Lake. The Indian River flows out of Burt Lake into Mullet Lake. The sturgeon populations of Burt, Mullet and Black lakes are essentially landlocked, connection with Lake Huron having been blocked by a dam with a lock on the Cheboygan River in the 1920s (Baker 1980).

Cheboygan River

There are now 48 dams in the Cheboygan River watershed (Godby et al. 2011). Lake sturgeon upstream migration and access to historic spawning grounds in the Cheboygan River is completely blocked by Cheboygan Dam at the mouth of the river (Auer 1996a; Godby et al. 2011).

Small numbers of remnant lake sturgeon were reported in the Cheboygan River from 1970-1980 below the paper mill dam in Cheboygan (Baker 1980). The Cheboygan River is thought to have a small lake sturgeon population of unknown size (Holey et al. 2000; Zollweg et al. 2003; Godby 2011). The run is currently considered to be extant, with the population size unknown, and occasional observations of adults (LHLSWG 2017).

Black Lake/Black River

The upper Black River drains into Black Lake, which in turn drains through the lower Black River into the Cheboygan River.

Black Lake had a “substantial” population of lake sturgeon (Baker 1980). Baker (1980) estimated a Black Lake population of lake sturgeon of 48.6 inches and larger at 1,666 fish in 1973; 2,478 fish in 1974; and 1,599 fish in 1975. However, legal and illegal harvest dramatically reduced the Black Lake population, with only 549 lake sturgeon 50 inches and larger remaining by 1999, a 66% decline from the 1975 estimate (Baker and Borgeson 1999). Capture of juvenile sturgeon provided evidence of recruitment to the spawning stocks for Black Lake (Baker and Borgeson 1999), but lake sturgeon harvest steadily declined from 1975 to 1999, with average weight and length of harvested lake sturgeon steadily increasing, indicating recruitment was not sufficient to keep up with harvest (Baker and Borgeson 1999).

Because of concern over future viability (Smith and Baker 2005), new restrictive harvest regulations were implemented in 2000 to protect the lake population from extirpation. Holey et al. (2000) and Zollweg et al. (2003) estimated the Black Lake sturgeon population only had about 60 remaining spawners. From 2000-2009 the fishery was regulated by implementing a limited entry fishery that could last 9 days or until a 5-fish quota was met. The minimum size of lake sturgeon that could be harvested was 36 inches. Harvest during 2000-2009 was at, slightly above, or below the quota of 5 fish (MDNR 2016b). Regulations were enacted for the upper section of the Upper Black River to protect spawning lake sturgeon, closing the river to fishing between Kleber Dam and Red Bridge. In 2010 MDNR determined that an unlimited entry fishery could be employed in Black Lake. Season length would be 5 days or until the state quota was met. During the 2011 season anglers harvested 11 lake sturgeon, exceeding the State's allocation by 4 fish (MDNR 2016b). In response, MDNR employed safeguards in 2012 to ensure that lake sturgeon harvest remained at or below the quota. The size limit was also removed to increase the likelihood of harvest of male and immature lake sturgeon and to reduce the harvest of mature female lake sturgeon.

In 2010 MDNR and local tribes agreed that the lake sturgeon population was estimated to exceed 750 mature fish, and a joint fishery was established. The tribes authorized harvest through a limited permit system. A protective exploitation rate of 1.2% of the estimated adult population was initially established. Since 2010, total lake sturgeon harvest in Black Lake by the tribes has ranged from 2-5 fish per year (MDNR 2016b). Since implementation of the joint fishery, the tribes have annually harvested below the annual tribal allocation of lake sturgeon regardless of differing methods and seasons employed among five tribes.

Lake sturgeon stocking began in Black Lake in 1982. Experimental streamside rearing was begun by MDNR in 2005, and a permanent rearing facility was constructed adjacent to Kleber Dam in 2009 (MDNR 2016b). A 2013 juvenile lake sturgeon survey in Black Lake suggested that natural reproduction is limited and unlikely to allow the population to reach established goals (MDNR 2016b).

By 2012, Hayes and Caroffino (2012) estimated a large, stable population in Black Lake of 1,125 adult fish. From 2001 through 2015 male and female adult lake sturgeon were captured and tagged during the spring spawning migration from Black Lake into the Upper Black River. Pledger et al. (2013) used these data to develop an appropriate population model for the Black Lake sturgeon population. Because it takes a number of years for this model to account for all individuals currently in the population (Pledger et al. 2013), initial apparent increases in abundance are artifacts of the accounting process used by the model. These annual abundance estimates indicate the sexually mature portion of the population has been increasing for both males and females, likely due to the stocking that took place in the 1980s. As of 2016, the model estimates 486 females and 627 males in the adult population in Black Lake (MDNR 2016b). The Black Lake sturgeon population is still below historical levels (MDNR 2016b).

The upper Black River, from its confluence with Black Lake to Kleber Dam, was the principal spawning area for the Black Lake population; sturgeon were also known to run down the lower Black River as far as Alverno Dam during the spawning season (Baker 1980). Lake sturgeon spawning in the Upper Black River is now limited to the lower 11 km of river by Kleber and Tower dams (Baker and Borgeson 1999). It is possible that prior to the construction of these dams spawning lake sturgeon migrated further upstream (Baker 2006). Alverno Dam in the lower Black River impounds a high gradient reach known as Smith Rapids, which historically provided sturgeon spawning habitat (Hay-Chmielewski et al. 1997). Zollweg et al. (2003) believed that lake sturgeon had been extirpated from the Black River, but Baker (2006) confirmed spawning in the Black River. Baker (2006) surveyed the Black River and Black Lake from 1997–2005 for adult and larval lake sturgeon, and captured 339 sturgeon (75–193 cm TL); as well as 104 larvae during two days of sampling in 1999. Baker and Smith (2005) estimated annual lake sturgeon spawning runs in the Upper Black River were similar in magnitude to spawning runs in the Sturgeon River, Michigan (58 to 135 individuals). Baker et al. (2008) intensively sampled spawning lake sturgeon over 6 consecutive years from 2001-2006 in the upper Black River; the number of fish sampled annually varied from 101 in 2004 to 234 in 2006. Lake sturgeon spawning has been reported recently in lower Black River in the area below Alverno Dam (Godby et al. 2011).

The MDNR objectives for Black Lake are to: develop a population of 1,600 to 2,000 adult lake sturgeon by 2030; achieve a natural recruitment level to sustain this population level; support a fishery with a maximum exploitation rate appropriate for the classification status as defined in their Rehabilitation Strategy; and determine habitat limitations of the Upper Black River and Black Lake by 2025 (MDNR 2016b).

<u>Mullet Lake</u>

Mullet Lake has its outlet into the Cheboygan River.

Mullet Lake had a smaller population of lake sturgeon than Black Lake (Baker 1980). Lake sturgeon utilized the Pigeon River as a spawning ground, but the extent of the spawning run and suitable spawning habitat was unknown (Baker 1980; Hay-Chmielewski and Whelan 1997). There have also been reports of lake sturgeon spawning in the Indian River tributary to Mullet Lake (Godby et al. 2011).

Hay-Chmielewski and Whelan (1997) made a population estimate of 300-700 sturgeon in Mullet Lake. Holey et al. (2000) and Zollweg et al. (2003) noted a small lake sturgeon population of unknown size in Mullet Lake. A fishing season for lake sturgeon in Mullet Lake was closed in 2000. A 2010 gillnet survey of Mullet Lake captured 70 lake sturgeon, most of which were relatively small and of hatchery origin (Baker 2010). From mark-recapture surveys, Baker (2010) estimated a population of 701 lake sturgeon in Mullet Lake. Hayes and Caroffino (2012) estimated a small population of less than 25 adult fish, well below minimum population viability.

<u>Burt Lake</u>

Burt Lake drains into the Indian River and into Mullet Lake.

Sturgeon fishing was ended in Burt Lake in 1974, at which time the population was believed to be very small (Baker 1980). Sturgeon from Burt Lake may have spawned in the Sturgeon River tributary, but the extent of the spawning run and suitable spawning habitat was unknown (Baker 1980). Hay-Chmielewski and Whelan (1997) made a population estimate of 10-100 lake sturgeon in Burt Lake. Holey et al. (2000) and Zollweg et al. (2003) noted a small lake sturgeon population of unknown size in Burt Lake. Hatchery lake sturgeon have been stocked in Burt Lake since 2003 (Baker 2011). A 2011 gillnet survey of Burt Lake captured 108 lake sturgeon, most of which were relatively small (with a few large adult fish) and of hatchery origin (Baker 2011). From mark-recapture surveys, Baker (2011) estimated a population of 1,535 lake sturgeon in Burt Lake, almost entirely small and immature stocked fish. Hayes and Caroffino (2012) estimated a small, stable population of 100 adult fish.

Thunder Bay River, Michigan

The Thunder Bay River flows into western Lake Huron.

Lake sturgeon formerly spawned in the Thunder Bay River (Hay-Chmielewski and Whelan 1997) but are now extirpated (Holey et al. 2000; Zollweg et al. 2003; LHLSWG 2017).

Au Sable River, Michigan

The Au Sable River flows into western Lake Huron on the lower peninsula.

Lake sturgeon formerly spawned in the Au Sable River (Hay-Chmielewski and Whelan 1997). Small numbers of lake sturgeon were reported in the Au Sable River from 1970-1980 below Foote Dam (Baker 1980).

Lake sturgeon were thought to be extirpated from the Au Sable River (Holey et al. 2000; Zollweg et al. 2003). Hayes and Caroffino (2012) estimated a small population of less than 25 adult fish, well below minimum population viability. The run is currently considered to be extant, with the population size unknown, and occasional observations of adults (LHLSWG 2017).

Rifle River, Michigan

The Rifle River enters Saginaw Bay in western Lake Huron.

Lake sturgeon spawning has been identified in the Rifle River (Elliott et al. 2008), but the population has been estimated to be only in the tens of individuals (Hay-Chmielewski and Whelan 1997, Holey et al. 2000). Hayes and Caroffino (2012) estimated a small population of less than 25 adult fish, well below minimum population viability. The run is currently considered to be extant, with occasional observations of spawning, and the annual spawning run size unknown (LHLSWG 2017).

Saginaw River, Michigan

The Saginaw River flows into Saginaw Bay in southwestern Lake Huron in Michigan. The river is formed by the confluence of the Tittabawassee and Shiawassee rivers southwest of Saginaw.

Lake sturgeon formerly spawned in the Saginaw River (Hay-Chmielewski and Whelan 1997). Historical anthropology records indicate that lake sturgeon was one of the most abundant fish species harvested by early aboriginal settlers to the Saginaw Valley, with large stocks migrating up the river to spawn each spring (Fitting et al. 1972; Boase 2007).

Holey et al. (2000) and Zollweg et al. (2003) believed that the Saginaw River had a remnant lake sturgeon population of unknown size. However, Boase (2007) sampled reaches of the Saginaw River from 2005 to 2007 using set-lines, bottom trawling and egg mats, to determine if lake sturgeon were utilizing the river for spawning. Boase (2007) captured no adult sturgeon nor located any sturgeon eggs. This research indicates that lake sturgeon are no longer spawning in the Saginaw River watershed, although sufficient spawning habitat exists below the Dow Dam on the Tittabawassee River and below the Hamilton Dam on the Flit River (Elliot et al. 2008). Hayes and Caroffino (2012) estimated that a small population of less than 25 adults remains in the Saginaw River, well below minimum population viability. The run is currently considered to be extant, with unknown population size, and occasional observations of adults (LHLSWG 2017).

The Saginaw River was identified by the Michigan Department of Natural Resources as having high suitability for rehabilitation or enhancement of lake sturgeon (Hay-Chmielewski and Whelan 1997). Beginning in 2018, MDNR will begin stocking fall fingerling lake sturgeon in the Saginaw River watershed; gametes will be collected by in southern Lake Huron in the Black River to rear 500 lake sturgeon fingerlings each at the Black River facility and Genoa National Fish Hatchery (LHLSWG 2017). If sufficient larval fish are collected in the Black River, these will replace the collected gametes. During each fall between 2018 and 2043, a target of 1,000 lake sturgeon will be stocked in the Saginaw River system. (LHLSWG 2017).

Tittabawassee River, Michigan

The Tittabawassee River is a tributary of the Saginaw River in Michigan.

Lake sturgeon formerly spawned in the Tittabawassee River tributary (Hay-Chmielewski and Whelan 1997).

Anecdotal reports by anglers indicate that adult lake sturgeon are occasionally captured or spotted in the Tittabawassee River during the spring below Dow Dam (Boase 2007). However, Boase (2007) sampled reaches of the Tittabawassee River from 2005 to 2007 using set-lines, bottom trawling and egg mats, to determine if lake sturgeon were utilizing the river for spawning. Boase (2007) captured no adult sturgeon nor located any sturgeon eggs. A single adult lake sturgeon was incidentally reported in the river directly below Dow Dam in May 2005, but it is unlikely that spawning took place (Boase 2007). The population is currently considered to be extant, but of unknown size, with occasional observations of adults (LHLSWG 2017).

In 2018, MDNR will begin annually stocking 125 fall fingerlings each from the Black River and Genoa hatcheries into the Tittabawassee River (LHLSWG 2017).

Shiawassee River, Michigan

The Shiawassee River is a tributary of the Saginaw River in Michigan.

Anecdotal reports by anglers indicated that adult lake sturgeon are occasionally captured or spotted during the spring below the Chesaning Dam on the Shiawassee River (Boase 2007). However, Boase (2007) sampled reaches of the Shiawassee River from 2005 to 2007 using set-lines, bottom trawling and egg mats, to determine if lake sturgeon were utilizing the river for spawning. Boase (2007) captured no adult sturgeon nor located any sturgeon eggs.

In 2018, MDNR will begin annually stocking 125 fall fingerlings each from the Black River and Genoa hatcheries into the Shiawassee River (LHLSWG 2017).

Cass River, Michigan

The Cass River is a tributary of the Shiawassee River in Michigan.

Anecdotal reports by anglers indicated that adult lake sturgeon are occasionally captured or spotted during the spring below the Frankenmuth Dam on the Cass River (Boase 2007). However, Boase (2007) sampled reaches of the Cass River from 2005 to 2007 using set-lines, bottom trawling and egg mats, to determine if lake sturgeon were utilizing the river for spawning. Boase (2007) captured no adult sturgeon nor located any sturgeon eggs.

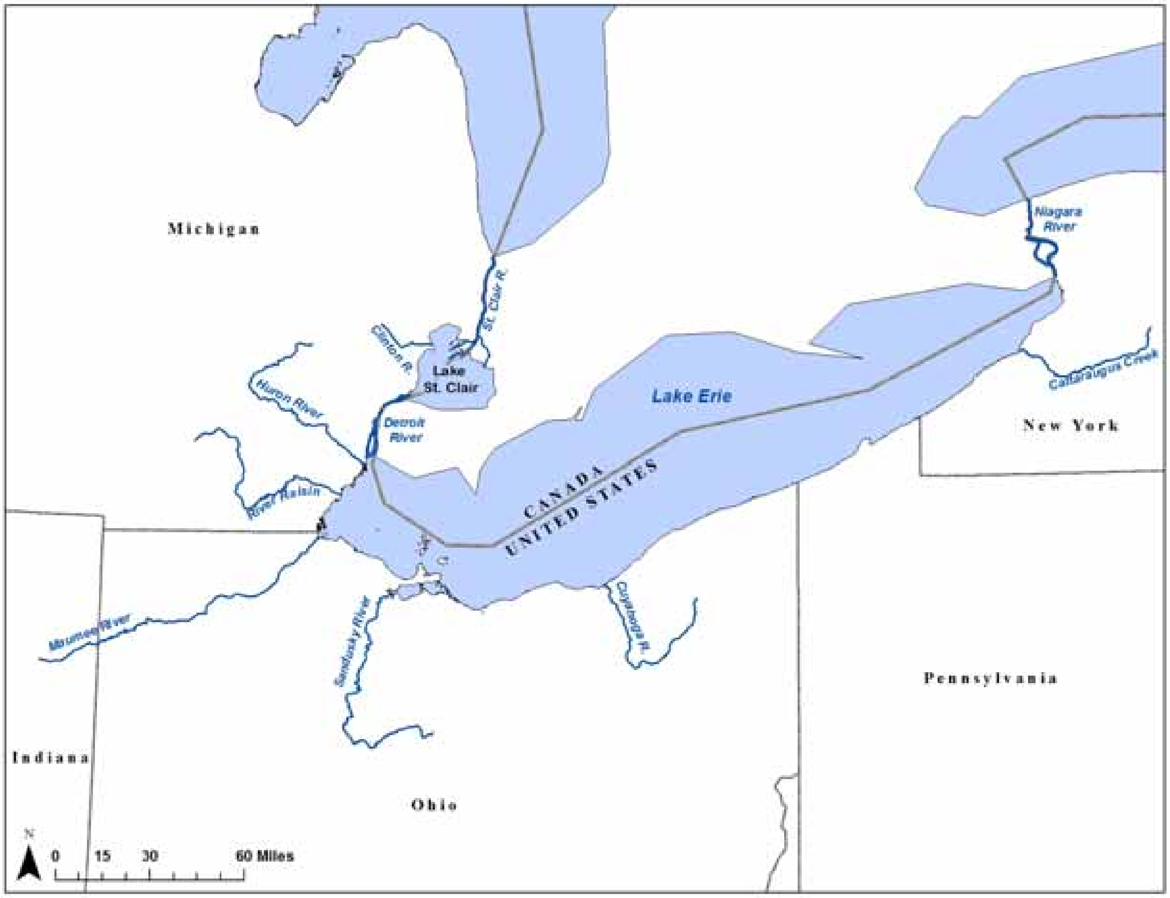
In 2018, MDNR will begin annually stocking 125 fall fingerlings each from the Black River and Genoa hatcheries into the Cass River (LHLSWG 2017).

Lake Erie

Basin-wide Distribution and Abundance

Lake sturgeon were historically extremely abundant in Lake Erie and its tributaries (MDNR 1973; Carlson 1995). Hay-Chmielewski and Whelan (1997) estimated that there were 535,000-580,000 lake sturgeon over 50 pounds in Lake Erie in 1885. Haxton et al. (2014) estimated that the biomass of lake sturgeon in Lake Erie was 56.03 million pounds in 1879. The historical commercial lake sturgeon catch in both U.S. and Canadian waters of Lake Erie was more than 1 million pounds annually from 1879-1906, with a peak catch of more than 5 million pounds in 1885 (Hartman 1973; Carlson 1995). The catch plummeted nearly 90% by 1897, declined rapidly to less than 40,000 pounds annually by 1920, and was down to 1,000 pounds annually by the late 1960s (Hartman 1973; Brousseau 1987; Caswell 2002).

At least 6 former lake sturgeon spawning populations in tributaries on the U.S. side of Lake Erie have been extirpated (Cuyahoga, Huron, Maumee, Raisin and Sandusky rivers, and Cattaraugus Creek), and the upper Niagara River is thought to have a very small remnant population. The only robust population is in the Huron-Erie corridor, with spawning in the Detroit River, Lake St. Clair and the St. Clair River, which are all connected waterways (Thomas and Haas 2002; Pratt 2008; Hayes and Caroffino 2012). Even the relatively large Lake St. Clair population is significantly reduced from historical numbers. Today there are small numbers of lake sturgeon present in Lake Erie, well below historical levels (ODNR 2015a).



Tributaries of Lake Erie with former and current lake sturgeon spawning populations

Huron-Erie Corridor

The St. Clair River drains Lake Huron into Lake St. Clair, forming part of the international boundary between Ontario and Michigan. Lake St. Clair then connects to Lake Erie through the Detroit River.

The Huron-Erie Corridor supports a robust lake sturgeon population of all age classes. Spawning populations are known in the St. Clair River, Lake St. Clair and the Detroit River. The Western basin of Lake Erie, the Detroit River east of Fighting Island, the North Channel of the St. Clair River and Anchor Bay in Lake St. Clair appear to be nursery areas for juveniles and foraging areas for adults (Elliott et al. 2008).

St. Clair River/Lake St. Clair, Michigan

Lake sturgeon were once extremely abundant throughout the St. Clair River (McCormick 1892) and spawned in both the river and Lake St. Clair (Hay-Chmielewski and Whelan 1997). Hay-Chmielewski and Whelan (1997) estimated that there were 112,000 lake sturgeon over 50 pounds in Lake St. Clair in 1885. Haxton et al. (2014) estimated that the biomass of lake sturgeon in Lake St. Clair was 7.62 million pounds in 1879. Peak harvest had likely passed when commercial harvest records were first documented in

Lake St. Clair, indicating that this estimate by Haxton et al. (2014) is below the real unexploited historical standing stock.

Very little was known about the lake sturgeon population of Lake St. Clair except that a substantial and largely illegal fishery occurred in the North Channel of the St. Clair River, a presumed spawning area, for many years (Baker 1980). Lake St. Clair and the St. Clair River apparently still supported a "significant" population of lake sturgeon in the early 1980s (Baker 1980).

Holey et al. (2000) and Zollweg et al. (2003) noted a lake sturgeon population of unknown size in Lake St. Clair and the St. Clair River. Spawning has been identified at two locations in the St. Clair River (Manny and Kennedy 2002). A mark-recapture population estimate of 45,506 lake sturgeon of all ages in the St. Clair system by Thomas and Haas (2002) was tenuous because of low recapture rates and because the St. Clair system is an open system with emigration and immigration of lake sturgeon possible from the Detroit River and Lake Erie. The Michigan Department of Natural Resources estimated that lake surgeon in the entire St. Clair basin including U.S. waters may be on the order of between 15,000 and 25,000 fish of all ages (COSEWIC 2006). Tag recapture data in the early 2000s provided an estimate for the Lake St. Clair component of approximately 5,000 individuals of all ages (COSEWIC 2006); some of these may be migrants from the Detroit and/or St. Clair rivers.

In 1995, the Ministry of Natural Resources and Forestry began a mark-recapture study in the Upper St. Clair River to gain a better understanding of lake sturgeon population demographics; tagging operations ceased in 2008. Overall, 1,657 lake sturgeon were marked and it was estimated that the lake sturgeon population was near 30,000 individuals (LHLSWG 2017). Pratt (2008) estimated a population of 20,000 to 40,000 lake sturgeon of all ages in the Lake St. Clair-River St. Clair system. Lake St. Clair supported a small commercial lake sturgeon fishery on the Ontario side as late as 2008 (Pratt 2008), but this fishery has since been closed (A. Welsh, pers. comm., 2016). Recovery and telemetry data from a more recent study indicated that approximately 15,000 to 20,000 sturgeon may reside in the North Channel of the St. Clair River and Lake St. Clair (USEPA 2009). Hayes and Caroffino (2012) noted a large, stable population and made an estimate of 15,882 adults. In 2012 the U.S. Fish and Wildlife Service, Ministry of Natural Resources and Forestry, and Purdy Fisheries resurrected lake sturgeon tagging operations in the Upper St. Clair River to obtain a more precise estimate of lake sturgeon abundance and to monitor trends in abundance over time; since 2012, 760 sturgeon have been tagged, with 174 tagged in 2017 (LHLSWG 2017).

Clinton River, Michigan

Lake sturgeon formerly occurred in the Clinton River, a tributary of Lake St. Clair (Hay-Chmielewski and Whelan 1997), but this population is now extirpated (A. Welsh, pers. comm., 2016).

Detroit River, Michigan

The Detroit River flows through southeastern Michigan, forming the border between Michigan and Ontario, Canada. The 51 km river is part of the channel connecting lakes Huron and Erie, and flows between Lake St. Clair and Lake Erie.

Historically, the Detroit River supported one of the largest lake sturgeon populations in the Great Lakes (McCormick 1892; Harkness and Dymond 1961; Caswell et al. 2002; USEPA 2015). Goodyear et al. (1982) reported the presence of seven historic lake sturgeon spawning sites in the Detroit River.

From the 1970s to 1999 no lake sturgeon spawning at all was reported in the Detroit River (USEPA 2015). Holey et al. (2000) and Zollweg et al. (2003) reported that the Detroit River had a small, remnant population of unknown size. Caswell (2003a, 2003b) captured 86 lake sturgeon in the Detroit River during 4 years of set line fishing. Caswell et al. (2002) noted that only 2 of 9 reported historical sturgeon spawning sites in the Detroit River still retained suitable spawning habitat for lake sturgeon, but underwater video detected no spawning sturgeon at these sites in 1998 and 1999 (McLain and Manny 2000). Caswell et al. (2002) found one previously unknown spawning site in 2001 on artificial substrate (a man-made bed of coal cinders), near Zug Island, verified by recovering sturgeon eggs deposited on collection mats in 2001 (Manny and Kennedy 2002; Caswell et al. 2002). It is suspected that few of the offspring from the Zug Island spawning site survived, due to chlorine pollution (Manny et al. 2004). Telemetry data suggested that several other possible spawning sites also may exist, however Caswell et al. (2002) were not able to verify spawning activity at those sites. Telemetry data by Caswell et al. (2002) suggest that the Detroit River is widely used by lake sturgeon from the Lake St. Clair population, but the extent and distribution of spawning activity in the Detroit River is unknown. No lake sturgeon were found in the Detroit River during 2003 and 2004 gill net, set line and egg mat surveys by the U.S. Fish and Wildlife Service and U.S. Geological Survey (Manny et al. 2004). The USFWS constructed an artificial spawning reef for sturgeon within the Detroit River near Fighting Island in 2008 (Hutton 2013).

Hayes and Caroffino (2012) reported that the Detroit River has a large, self-sustaining and stable lake sturgeon population, estimated at 4,838 adults, based on mark-recapture analysis by the U.S. Fish and Wildlife Service. Hutton (2013) reported on USWFS monitoring in the Detroit River since 2003 that produced an estimate of 5,000 individual lake sturgeon utilizing the Detroit River during the spawning season. It is unclear if these recent population estimates include fish from Lake St. Clair and the St. Clair River. Genetic data suggest that the Detroit and St. Clair populations are a single population (A. Welsh, pers. comm., 2016). However, acoustic migration tagging by Kessel et al. (2018) indicates that lake sturgeon in the Detroit and St. Clair rivers represent two semi-independent populations that could require separate management consideration for their conservation.

<u>Huron River, Michigan</u>

The Huron River is a western tributary of Lake Erie in Michigan.

A former lake sturgeon spawning population in the Huron River is now extirpated (Hay-Chmielewski and Whelan 1997; Zollweg et al. 2003).

<u>River Raisin, Michigan</u>

The River Raisin flows through southeastern Michigan into western Lake Erie.

A former lake sturgeon spawning population in the River Raisin is now extirpated (Hay-Chmielewski and Whelan 1997; Zollweg et al. 2003).

Maumee River, Ohio/Indiana

The Maumee River flows through from northeastern Indiana and northwestern Ohio into southwestern Lake Erie.

Lake sturgeon historically migrated as far up the Maumee River system as the Ottawa River (Carlson 1995). Lake sturgeon access to historic spawning grounds in the Maumee River is now blocked by Independence Dam, 77 km upstream from Lake Erie (Auer 1996a).

Lake sturgeon are now extirpated from the Maumee River (Holey et al. 2000; Zollweg et al. 2003). Survey work conducted in 2005 and 2006 confirmed that no lake sturgeon spawning is taking place in the Maumee River (Elliott et al. 2008).

Sandusky River, Ohio

The Sandusky River is a tributary of Lake Erie in Ohio.

Sandusky, Ohio was the location of a very large commercial sturgeon smoking operation beginning in 1860 (In 1872 the fishery reported that 13,880 sturgeon averaging 50 pounds each were smoked), but the sturgeon were brought there from throughout the Great Lakes (MDNR 1973; Houston 1987).

A former lake sturgeon spawning population in the Sandusky River has been extirpated (Zollweg et al. 2003).

The Ballville Dam, built in 1913 at river km 29 on the Sandusky River is proposed for removal (USFWS 2014).

Cuyahoga River, Ohio

The Cuyahoga River is a tributary of Lake Erie in Ohio.

A former lake sturgeon spawning population in the Cuyahoga River has been extirpated (Auer 1996a). Planning is underway to remove the 8-foot high Brecksville Dam from the Cuyahoga River.

Cattaraugus Creek, New York

Cattaraugus Creek flows into southeastern Lake Erie.

A former lake sturgeon spawning population in Cattaraugus Creek has been extirpated (Holey et al. 2000; Zollweg et al. 2003). Cattaraugus Creek has possible spawning habitat, but no recent lake sturgeon observations (NYSDEC 2017).

Lake Erie Outlet/Buffalo River

The Lake Erie outlet in the vicinity of Buffalo is a lake sturgeon spawning and staging area, which had a historic fishery (NYSDEC 2017). There is potential for sturgeon spawning in the Buffalo River (NYSDEC 2017). The 2016 population estimate for the Buffalo Harbor breeding aggregation is 806 fish, with a range of 457 to 1,515 at the 95% confidence interval (NYSDEC 2017). The sampled population is predominantly male and less than 30 years old. Few juvenile lake sturgeon are captured from year to year, making determination of recent recruitment difficult. However, sturgeon as young as 8 years old have recruited to the gill nets used to assess spawning adults in this location (NYSDEC 2017).

In the Lake Erie basin of New York, lake sturgeon spawning habitat likely occurs along the shoreline and on reef habitats, as well as the Upper Niagara River and some tributaries. It is uncertain where spawning is actually occurring, but adult aggregations are easily sampled in the vicinity of Buffalo during the spring (NYSDEC 2017). NYSDEC has been monitoring a congregation of young adult lake sturgeon at the head of the Upper Niagara River at spawning time, and has documented natural reproduction in Buffalo Harbor. No spawning activity has been observed in New York's portion of the lake or tributaries in recent history, so it is difficult to determine whether the fish captured at Buffalo Harbor were spawned nearby or migrated from other parts of the lake (NYSDEC 2017).

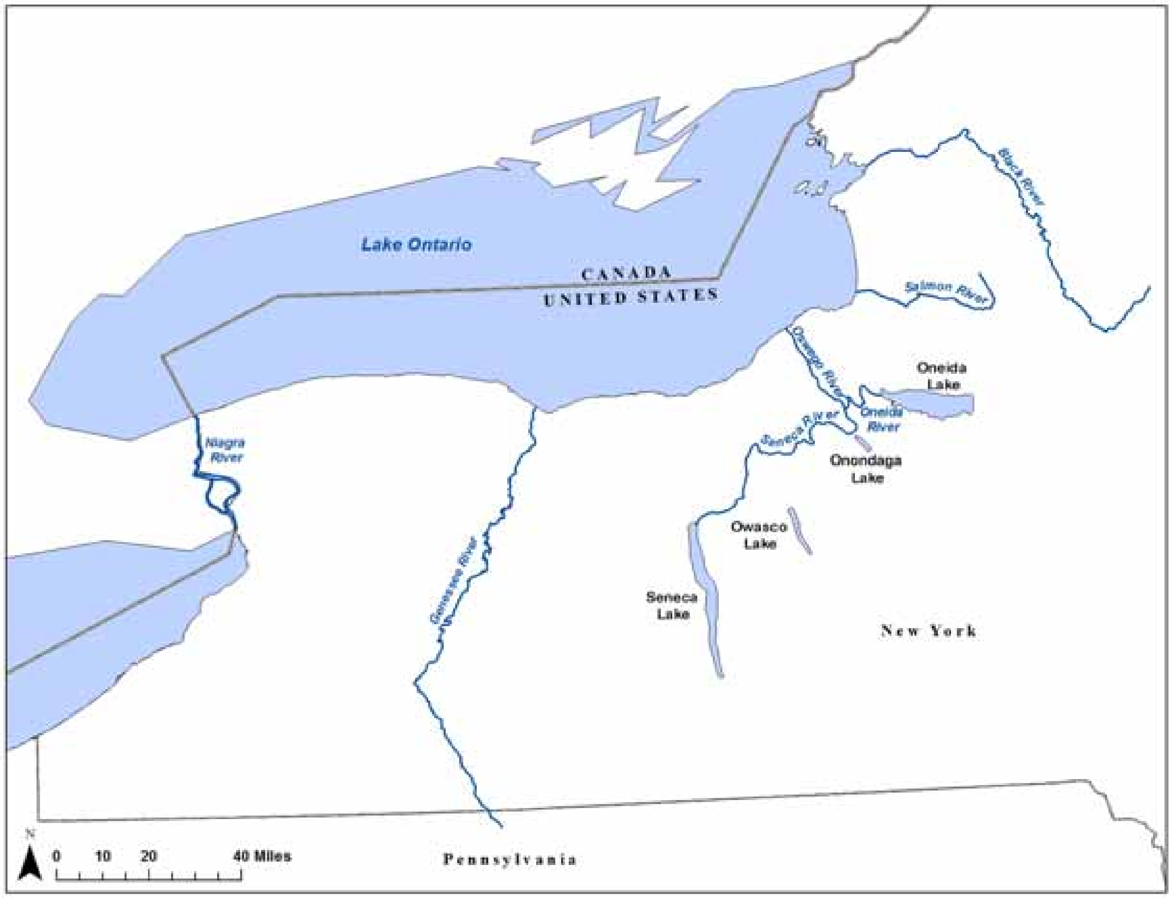
Upper Niagara River, New York

The Niagara River flows north from Lake Erie and connects into Lake Ontario. The river is often described as a strait. The upper Niagara River is upstream of Niagara Falls.

During the 1800s, large harvests of lake sturgeon were taken from the Niagara River, with 14 tonnes taken in 1900 alone (Carlson 1995). Commercial catch records for the Niagara and St. Lawrence rivers were not usually separated – collectively the catch was 4-10 tonne/year from 1923-1952; Niagara River landings alone were 2.5 tonnes in 1930 (Carlson 1995). The lake sturgeon population in the Niagara River sustained commercial harvests into the 1940s and 1950s (Carlson 1995). A former sturgeon spawning shoal in the upper Niagara River in front of Buffalo Harbor was subsequently dredged (Greeley 1929; Carlson 1995), and reports of lake sturgeon in the Niagara River became relatively rare (Chalupnicki et al. 2011).

Holey et al. (2000) and Zollweg et al. (2003) noted a remnant lake sturgeon population of unknown size in the upper Niagara River. Some successful spawning activity has been documented in the Niagara River recently (Welsh 2004; Chalupnicki et al. 2011), but population numbers are still largely unknown. Carlson (2011) noted lake sturgeon spawning in the upper Niagara River at Buffalo Harbor. Lake sturgeon spawning areas have also been identified in Lake Erie 13-19 km offshore over rock crevices near Dunkirk and at Silver Creek along the eastern Lake Erie shoreline (Carlson 1995). The upper Niagara River is a known adult sturgeon concentration area (NYSDEC 2017).

Lake Ontario



U.S. tributaries of Lake Ontario with former and current lake sturgeon spawning populations

Basin-wide Distribution and Abundance

Though once isolated by Niagara Falls, Lake Ontario is now connected to the Great Lakes via locks in the Welland Canal (Welsh et al. 2008). Historically, lake sturgeon were abundant in Lake Ontario and its tributaries. Haxton et al. (2014) estimated that the biomass of lake sturgeon in Lake Ontario was 8.46 million pounds in 1879. Peak harvest had likely passed when commercial harvest records were first documented in Lake Ontario, indicating that this estimate by Haxton et al. (2014) is below the real unexploited historical standing stock. During the 1800s, large quantities of lake sturgeon were harvested from Lake Ontario (Carlson 1995). The peak commercial harvest of lake sturgeon in Lake Ontario was more than 225,000 kg in 1890 (COSEWIC 2006). By 1900 the population had crashed due to over-fishing such that the commercial catch was insignificant (Christie 1973). Lake Ontario sturgeon are no longer a lake-wide resource (Carlson 1995).

All of the former lake sturgeon spawning populations in tributaries on the U.S. side of Lake Ontario have either remnant spawning populations or are extirpated, with small populations known to remain in the Black, Genesee, lower Niagara and Oswego rivers and in Oneida Lake. In Canadian tributaries of Lake Ontario, lake sturgeon spawning has only been documented in the Trent River on an infrequent basis (USEPA 2009).

The New York State Department of Environmental Conservation initiated a Lake Ontario lake sturgeon stocking program in 1995, and stocking has occurred in the Black, Genesee, Indian, lower Niagara, Oswegatchie, Raquette, Salmon and St. Regis rivers, and in Black, Cayuga and Oneida lakes (Klindt and Adams 2005; Brooking et al. 2011; Chalupnicki 2011; Holbrook 2013a).

Lower Niagara River, New York

The Niagara River flows from Lake Erie into Lake Ontario. The lake sturgeon population in the upper Niagara River is separated by Niagara Falls, and was discussed in the section on Lake Erie. Lake sturgeon in the lower Niagara River are genetically indistinguishable from those in the St. Clair River (Welsh et al. 2008).

Lake sturgeon waters downstream of Niagara Falls were without barriers historically, but these habitats have been fragmented by dams (Carlson 1995). Anecdotal accounts from the 1940s suggest that the lower Niagara River lake sturgeon population was already below its historic peak at that time (Hughes et al. 2005).

From 1980 to 1994, there were only two confirmed captures of lake sturgeon in the lower Niagara River (Carlson 1995). Age analysis of lake sturgeon captured in the lower Niagara River did indicate some successful reproduction in the mid-1990s (Elliot et al. 2008; USEPA 2009). Holey et al. (2000) and Zollweg et al. (2003) reported a small, remnant lake sturgeon population of unknown size in the lower Niagara River below Niagara Falls. The lower Niagara River lake sturgeon population has declined since the 1940s and is probably small relative to its historic abundance (Hughes et al. 2005).

There has been restoration stocking of lake sturgeon in the lower Niagara River, and successful spawning has been documented on an infrequent basis since the stockings (Hughes et al. 2005; Elliott et al. 2008). Hughes et al. (2005) captured 67 sturgeon ranging from 1 to 23 years in age in the lower Niagara River using several capture methods, but 47 of the 61 fish that were aged (77%) were younger than age 10. Carlson (2011) noted lake sturgeon spawning in the lower Niagara River at Art Park. Trometer et al. (2011) began a mark-recapture study in 2010 to estimate the abundance and survival of lake sturgeon in the lower Niagara River and Niagara Bar at Lake Ontario; larval, egg and juvenile surveys are also planned. There is lake sturgeon spawning habitat in the gorge in the lower Niagara River, and Niagara Bar is a known sturgeon congregation and feeding area (NYSDEC 2017).

Reproduction is likely occurring in the lower Niagara River, with several young adult year classes documented over time (Biesinger et al. 2014). The USFWS estimated a population of 7,600 individuals with a range of 5,900 and 9,800 individuals at the 95% confidence interval (NYSDEC 2017). Age estimates of sampled lake sturgeon show that 92% of sturgeon captured in the lower Niagara River originated from the 1992-2004 year classes with little to no recruitment being detected from other years (NYSDEC 2017). This was inspected for a sampling bias of certain aged fish and was found not significant. Possible explanations for the failure to detect younger year classes of lake sturgeon are habitat changes in the sampling area making it less attractive to juvenile sturgeon, or a lack of appreciable recruitment in recent years.

Genesee River, New York

The Genesee River is one of the major tributaries flowing into Lake Ontario. The Genesee River Falls is an impassable waterfall at river kilometer 10.2, restricting potential sturgeon habitat to the lower Genesee River from the falls north to Lake Ontario (Dittman and Zollweg 2004).

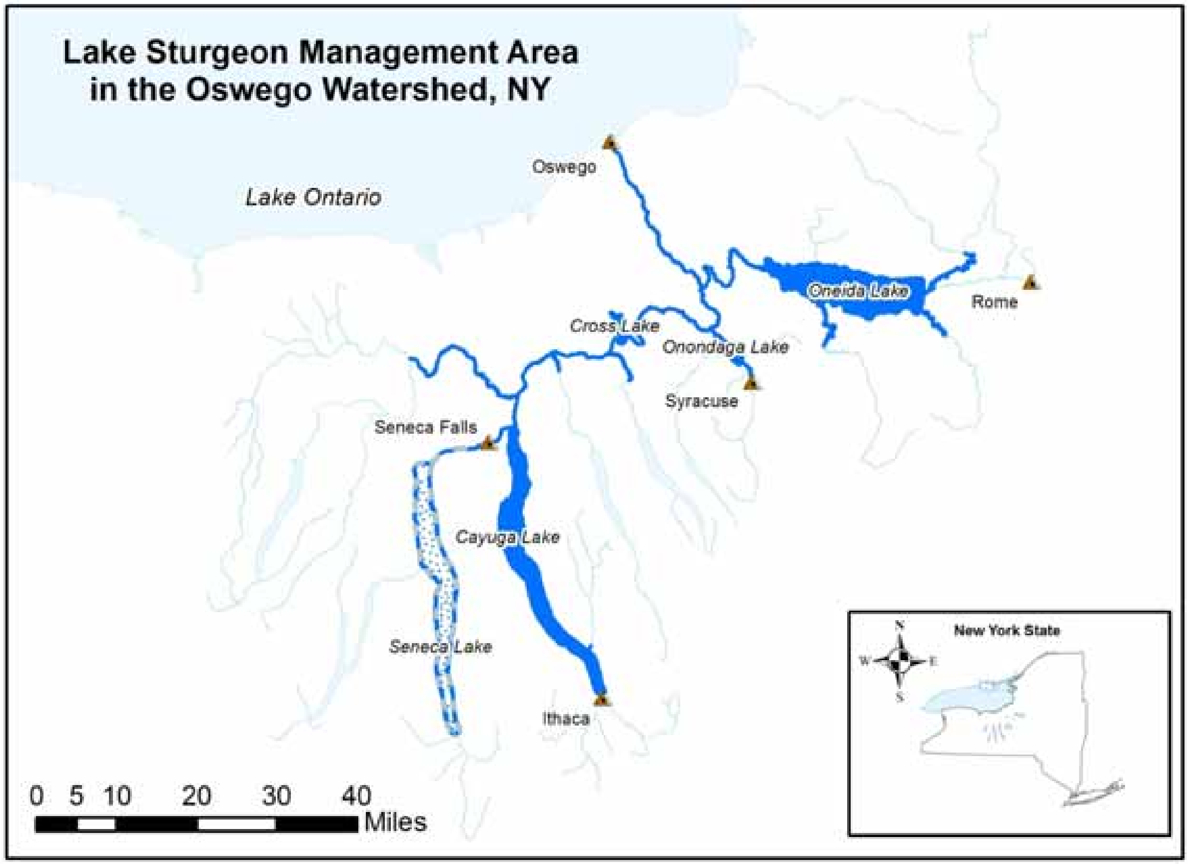
There was a “substantial” sturgeon presence and very large "monster" sturgeon (45 to 70 kg) in the lower river historically and congregations of spawning sturgeon were reported at the falls (Greeley 1927; Black 1944; Clune 1963; Carlson 1995; Dittman and Zollweg 2004). Lake sturgeon were reported infrequently in the Genesee River in the early 1990s and 2000s (Carlson 1995; Carlson and Daniels 2004), but there have been no records of spawning sturgeon in the river since the 1920s (Greeley 1927; Carlson 1995). Holey et al. (2000) and Zollweg et al. (2003) considered the former spawning population of lake sturgeon to be extirpated.

Stocking of 1,900 hatchery lake sturgeon from St. Lawrence River stock occurred in the Genesee River in 2003 and 2004 (Dittman and Zollweg 2004; Dittman 2008; Elliott et al. 2008; Chalupnicki et al. 2011; Dittman 2011a), and from 2013-2016 (NYSDEC 2017). Released juvenile sturgeon were successfully using about 9 km of low-gradient accessible habitat (Dittman 2008). By 2009, 733 stocked sturgeon had been recaptured and tagged; the average size was 65.8 cm and 1.6 kg (Dittman 2011a). Fingerling lake sturgeon from the NYSDEC Oneida Fish Hatchery were stocked into the Genesee River 2013-2016 (Holbrook 2013a; NYSDEC 2017). The lake sturgeon stocked in 2003 and 2004 were estimated to have an overall survival rate of 26%, resulting in a population estimate of about 494 for those two year classes, and recent stocking is expected to have a similar survival rate (NYSDEC 2017). Based on that survival rate and the numbers of stocked fish, the overall population is estimated to be 1,288 sturgeon ranging in age from 1 to 14, in 6 cohorts as of 2016 (NYSDEC 2017). By 2015, few of the 2003 and 2004 stocked sturgeon remained resident in the Genesee River (NYSDEC 2017). However, ripe males from those cohorts were captured in spring of 2016 in the river; the stocked female population in the Genesee River will reach the age of maturity by 2020 and evidence of successful spawning is not expected until then (NYSDEC 2017).

Oswego River Watershed, New York

The Oswego River watershed includes the drainages of the Oswego, Oneida, Seneca and Clyde rivers. The watershed includes a series of Finger Lakes, including Owasco, Cayuga and Seneca lakes; and Oneida, Onondaga, and Cross lakes (Brooking 2011). The Oswego River flows across the central lowlands before entering southern Lake Ontario.

Prior to dam and canal construction in the early 1800s, the falls and rapids in the lower Oswego River at river km 11-15 may have been a barrier to the upstream movement of lake sturgeon in the system (Carlson 1995; Brooking et al. 2011). Sturgeon were not reported from the Oswego River system above Oswego falls prior to canal construction and were absent from older Native American, Jesuit missionary and explorer accounts from the region (Brooking et al. 2011). The Falls of Oswego were described by early explorers as passable downstream only in an unloaded boat and were definitely passable by Atlantic salmon, suggesting there would have been years that lake sturgeon could have ascended the falls, but whether lake sturgeon reproduced and maintained populations in upstream areas of the Oswego River system is unknown (Carlson 1995).



Lake sturgeon management area in the Oswego River watershed (from Brooking et al. 2011)

Locks and canals constructed for navigation before the 1830s could have allowed sturgeon to bypass the falls (Carlson 1995). Reports of sturgeon in the watershed began in the mid-19th century and these may have been transitory fish that arrived via canals (Brooking et al. 2011). Verifiable reports of lake sturgeon were made in several locations in the watershed between 1900 and 1994 before stocking began, indicating that sturgeon had at least intermittent access to the Oswego watershed from Lake Ontario and that this basin was able to provide at least the necessary habitat to support transient fish (Brooking et al. 2011). Whether or not populations of sturgeon stayed in this part of the system for their entire life cycle remains obscure (Brooking et al. 2011).

The Erie and Barge canals now extend east-west through the watershed and provide connections via water channel to adjacent watersheds. There are numerous barriers such as locks and dams which hamper fish movement throughout the basin.

Lake sturgeon were stocked in the Oswego River watershed from 1995-2004, using fish from two populations in the St. Lawrence River and from the Des Prairies River in Quebec (Brooking 2011; Welsh 2011). An overall population estimate for the Oswego River watershed was made of 2,891 sturgeon between the ages of 1 and 22 years old

(NYSDEC 2017). The majority of the sturgeon are 22-year-old fish from the 1995 stocking of lake sturgeon originating from Riviére des Prairies, Quebec brood stock (NYSDEC 2017).

Oswego River

The mouth of the Oswego River once provided spawning habitat for Lake Ontario lake sturgeon (Carlson 1995). A 1982 report of lake sturgeon spawning at Varick Dam in the lower Oswego River was one of only two records of sturgeon seen in the system since the 1960s, until a few infrequent reports of sightings in the early 1990s (Brooking et al. 2011). Holey et al. (2000) and Zollweg et al. (2003) thought that the former lake sturgeon population in the lower Oswego River had been extirpated. Brooking (2011) noted that spawning congregations of lake sturgeon have not been seen recently in the lower reaches of the Oswego River, though there is still suitable spawning habitat. Lake sturgeon have been captured in the mouth of the Oswego River below the dam at the power station (NYSDEC 2017). Potential spawning areas may exist in the lower Oswego River but need to be investigated (NYSDEC 2017).

Hatchery sturgeon stocked into Oneida and Cayuga lakes have been documented migrating into the Oswego River (Dittman 2011b). By 2009, the average size of stocked sturgeon in the Oswego River was 1.3 m and 11.94 kg (Dittman 2011b).

Oneida Lake/Fish Creek

The earliest record of lake sturgeon in the Oswego River watershed was a large adult that was documented in Oneida Lake in 1856 (Brooking et al. 2011).

Hatchery-produced juvenile lake sturgeon were stocked into Oneida Lake (8,127 fish) from 1995-2004 (Chalupnicki et al. 2011; Dittman 2011b). Survival rates of sturgeon stocked in Oneida Lake have been “substantial” with 40% of fish stocked in 1995 present in 2002 (Brooking et al. 2011). Sturgeon stocked in Oneida Lake have exhibited extremely high growth rates; those of juvenile and sub-adult fish are higher than any other sturgeon population found in the literature (Brooking et al. 2011). By 2011, some male sturgeon stocked in Oneida Lake had reached 4-5 feet in length and were staging during the spring in potential spawning areas such as Fish Creek (Figura 2011). Oneida Lake plays a crucial role in the NYSDEC overall lake sturgeon management plan for the Oswego River watershed because of its large size, favorable habitat, and the apparent success of previous sturgeon stocking efforts (Brooking et al. 2011). Young sturgeon spawned by stocked populations were detected recently in Oneida Lake; researchers have captured wild produced fish from the 2011, 2012, 2014 year classes (NYSDEC 2017). Lake sturgeon spawning is suspected in Fish Creek, due to recent captures of wild recruit fish (NYSDEC 2017).

Oneida River

Stocking of lake sturgeon from St. Lawrence River stock has occurred in Oneida Lake from 1995-2004, and from 2014-2016 (NYSDEC 2017). Outmigration from Oneida Lake has resulted in sturgeon reports from the Oneida River (Brooking et al. 2011). Lake sturgeon spawning is suspected at Caughdenoy Dam (NYSDEC 2017).

Seneca River/Cross Lake

There was one report of lake sturgeon in the Seneca River prior to 1900 (Brooking et al. 2011). Lake sturgeon were reported in the Cross Lake portion of the Seneca River in about 1950-60s (Brooking et al. 2011). Lake sturgeon were reported infrequently in the Seneca River in the early 1990s (Brooking et al. 2011).

Cross Lake is connected to the Oswego River system and may provide enough of the resources necessary to support various lake sturgeon life stages (Brooking et al. 2011). Hatchery sturgeon stocked into Oneida and Cayuga lakes have been documented migrating into the Seneca River (Dittman 2011b). By 2009, the average size of stocked sturgeon in the Seneca River was 1.21 m and 9.03 kg (Dittman 2011b). Ripe females have been captured in the Seneca River since 2013 (NYSDEC 2017). Lake sturgeon spawning is suspected at artificial spawning beds at Mud Locks in the Montezuma National Wildlife Refuge (NYSDEC 2017).

Seneca Lake

Lake sturgeon were reported in Seneca Lake around 1900 (Brooking et al. 2011).

Cayuga Lake

There was a report of lake sturgeon in Cayuga Lake as early as 1880 (Brooking et al. 2011). The pre-1880s population in Cayuga Lake may have been relict and of low abundance, with reports from 1889 that more were caught in earlier years; the largest lake sturgeon caught by angling from Cayuga Lake in the 1880s was 16 kg, suggesting poor growth conditions or a young-aged population (Brooking et al. 2011). The Cayuga Lake sturgeon population was presumed to have been an isolated group of adult fish that migrated over the Oswego Falls and resided in Cayuga Lake for decades (Brooking et al. 2011). Lake sturgeon were reported from the Cayuga-Seneca Canal, which connects the Erie Canal to Cayuga Lake and Seneca Lake, in 1908 (Brooking et al. 2011). Lake sturgeon were reported in Cayuga Lake as recently as 1961 (Brooking et al. 2011).

Hatchery-produced juvenile lake sturgeon were stocked into Cayuga Lake (3,782 fish) sporadically from 1995-2004 (Chalupnicki et al. 2011; Dittman 2011b). Of the Finger Lakes, NYSDEC lake sturgeon management efforts focus on Cayuga Lake because it is connected to the canal and river system by the Seneca-Cayuga Canal, and previous sturgeon stocking has been successful there in the past (Brooking et al. 2011). Fingerling lake sturgeon from the NYSDEC Oneida Fish Hatchery were stocked into Cayuga Lake from 2013-2016 (Holbrook 2013a; NYSDEC 2017). Survival of stocked fish to maturity has been documented through annual fall netting of adults (NYSDEC 2017). Abundant sea lamprey populations in Cayuga Lake are thought to have hampered survival of stocked sturgeon, though efforts at sea lamprey control have resumed (NYSDEC 2017). Fish stocked in 1995 were preparing to spawn for the first time in Cayuga Lake in 2014 (MacCarald 2014). There has been recent observed spawning activity (spring 2017) in the Fall Creek tributary (NYSDEC 2017).

Onondaga Lake

Outmigration from Oneida Lake has resulted in sturgeon reports from Onondaga Lake (Brooking et al. 2011). Onondaga Lake is connected to the Oswego River system and may provide enough of the resources necessary to support various lake sturgeon life stages (Brooking et al. 2011).

Owasco Lake

Lake sturgeon were reported in Owasco Lake in 1986 (Brooking et al. 2011).

Owasco Lake is separated from the Oswego River system by barriers that are likely to be impassable to sturgeon, and is not considered a target area for lake sturgeon restoration by the NYSDEC (Brooking et al. 2011).

Salmon River, New York

The Salmon River is a tributary of eastern Lake Ontario. The Salmon River has been reconnected to the St. Lawrence River by removal of the Fort Covington Dam in 2009 (NYSDEC 2017).

The Salmon River was a historic lake sturgeon spawning habitat (NYSDEC 2017). Zollweg et al. (2003) thought that lake sturgeon had been extirpated from the Salmon River mouth. Carlson and Daniels (2004) believed that lake sturgeon probably occurred in the lower Salmon River, although there were no authenticated records. COSEWIC (2006) noted that spawning lake sturgeon had been sighted in the Salmon River.

The NYSDEC began stocking fingerling lake sturgeon from the Genoa National Fish Hatchery in Wisconsin into the Salmon River (Holbrook 2013a). Stocking of lake sturgeon from St. Lawrence River stock has occurred in the Salmon River from 2012-2016 (NYSDEC 2017). There is an ongoing Native American sturgeon fishery in the Salmon River, within the sovereign territory of the St. Regis Mohawk Tribe and the adjoining Mohawk Council of Akwesasne First Nation lands in Canada (NYSDEC 2017).

Black River, New York

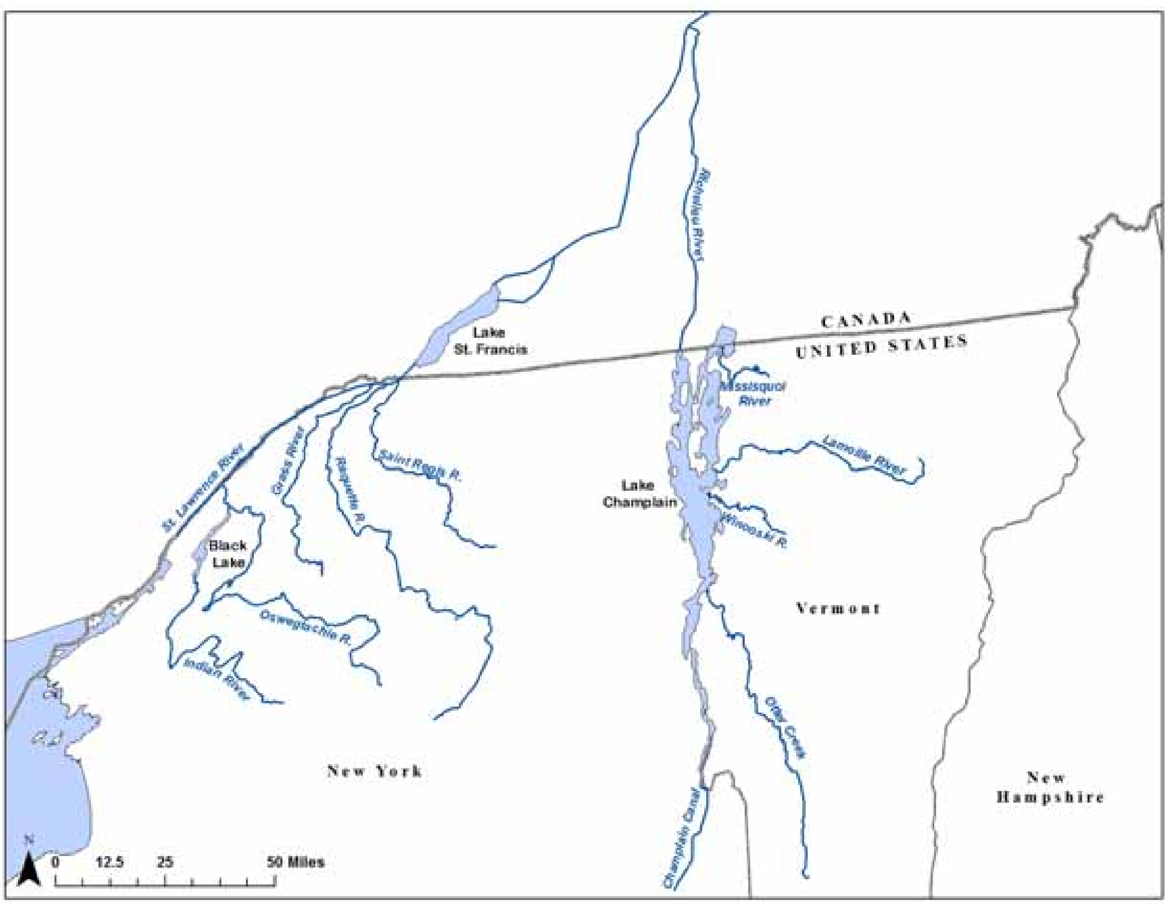
The Black River flows into eastern Lake Ontario.

Historically the Black River was known for its large sturgeon (Klindt and Gordon 2011). Lake sturgeon spawned up to waterfalls at river km 14 (Carlson 1995). Lake sturgeon access to historic spawning grounds in the Black River was blocked by construction of a dam 1.6 km upstream of the river mouth at Dexter (Auer 1996a).

Based on anecdotal and photographic information, a lake sturgeon fishery existed in the Black River into the 1940s (Klindt and Gordon 2011). Jolliff and Eckert (1971) documented lake sturgeon spawning near Dexter. A single lake sturgeon was incidentally caught in the Black River near Watertown (km 13) in 1990, but all earlier sightings were downstream of the rapids at Dexter (Carlson 1995). By 1995, fishways for passage of salmonids around the dams at Dexter and Glen Park (km 9.5) apparently allowed a juvenile lake sturgeon (91 cm) to reach Great Falls under Mill Street (km 14) in Watertown, the historic barrier to all migratory fish from Lake Ontario (Carlson 1995).

Holey et al. (2000) and Zollweg et al. (2003) reported that a small, remnant lake sturgeon population of unknown size remained in the Black River. Lake sturgeon were observed in the lower Black River at Dexter in 1995 by NYSDEC fisheries staff, and by anglers in 2003-2004 (Klindt and Gordon 2011). In May 2005, 11 adult lake sturgeon in spawning condition were captured in the lower river and a single sturgeon egg was captured in an egg trap, indicating a spawning event had taken place; and in May 2006, 5 lake sturgeon were netted which could have been pre- or post-spawning fish (Klindt and Gordon 2011). Klindt and Adams (2005) noted that there had been successful spawning documented since stockings of lake sturgeon in the Black River. Elliott et al. (2008) characterized spawning as "suspected" in the Black River. In April 2009, 5 ripe male sturgeon were captured at Dexter; and in April 2010, 27 lake sturgeon were captured at Dexter, mostly ripe males (Klindt and Gordon 2011). Carlson (2011) noted spawning of lake sturgeon in the Black River at Dexter. Lake sturgeon tagged in Oneida Lake have been recovered in the Black River (NYSDEC 2017). 152 individual lake sturgeon have been tagged in the Black River by NYSDEC between 2009 and 2016 (NYSDEC 2017).

St. Lawrence River



St. Lawrence River and U.S. tributaries with former and current lake sturgeon spawning populations

Basin-wide Distribution and Abundance

A large commercial fishery existed in the St. Lawrence River basin between the mid-1800s and early 1900s, which dramatically reduced lake sturgeon populations (COSEWIC 2006). Lake sturgeon catches in the upper St. Lawrence River sustained a limited commercial lake sturgeon fishery beyond the collapses of the fisheries in the upstream Great Lakes (Zollweg et al. 2003). The U.S. harvest continued through the 1960s, until declines were recognized and the fishery closed in 1976 (Zollweg et al. 2003). Commercial harvest in Canadian waters of the St. Lawrence began in 1920 and ended in 2005; Canadian catches remained fairly consistent from 1920 to 1984 (attributable to the productivity of the system and to a relatively low annual harvest that was focused on sub-adults and smaller adults, and restricted to specific zones), with the maximum harvest being in 1995, at 245,700 kg (COSEWIC 2006). However, by 1987 the Canadian component of the St. Lawrence population was considered overexploited (COSEWIC 2006). Despite increasingly stricter Canadian fishing regulations and recovery efforts the decline in the lake sturgeon population continued in the St. Lawrence River, probably due to overfishing (COSEWIC 2006), and abundance has still not recovered from 19th century declines (NYSDEC 2014). There is still a large commercial lake sturgeon fishery in the Quebec waters of the St. Lawrence.

In the U.S. waters of the St. Lawrence River, lake sturgeon appear to remain relatively common in a few areas, notably upper Lake St. Francis, between Moses Dam and the New York State border, and near Waddington, New York. However, most former lake sturgeon populations in the St. Lawrence River and its tributaries (Grasse, Indian, Oswegatchie, Raquette and St. Regis rivers and Black Lake) are remnant or extirpated. Small lake sturgeon spawning populations remain in 3 of 4 Lake Champlain tributaries that were known historic spawning sites (Lamoille, Missisquoi and Winooski rivers).

Although all 14 historically known Canadian population components in the St. Lawrence River and tributaries are extant, 12 are considered small and only 2 are large (Holey et al. 2000). Spawning is known to occur at 6 sites, is probably not occurring at 2 sites, and is unknown at 6 sites (Holey et al. 2000). Of the known Canadian spawning populations, 4 have spawning runs of <1,000 individuals; the spawning run in the St. Maurice River has ~1,250 individuals; and the Des Prairies River has ~7,000 individuals (Holey et al. 2000; Fortin et al. 2002). Lac St. Pierre also has a notable spawning population (Elliott et al. 2008; USEPA 2009).

Lake sturgeon access is inhibited for many of the historical spawning grounds in St. Lawrence tributaries by small dams; and within the St. Lawrence River by the Moses-Saunders Dam at Massena, completed in 1958, which blocks movement of lake sturgeon into the upper river and Lake Ontario (Carlson 1995; Elliott et al. 2008; USEPA 2009). Lake sturgeon populations in the St. Lawrence River watershed have been isolated and fragmented by the construction of numerous hydroelectric facilities (Pratt 2008).

Lake sturgeon have been stocked into the St. Lawrence River and some of its tributaries, including the Oswegatchie, Grasse, Raquette and St. Regis rivers and Black Lake (Elliott et al. 2008; USEPA 2009), but stocking efforts have not been hugely successful (Heuvel and Edwards 1996; Chalupnicki et al. 2011) and spawning of stocked fish has only been documented in the Oswegatchie River so far.

St. Lawrence River, New York

The St. Lawrence River originates at the outflow of Lake Ontario, connecting the Great Lakes with the Atlantic Ocean and forming the primary drainage outflow of the Great Lakes Basin. The upper river, extending from Lake Ontario into Quebec, is freshwater. Within New York State the river acts as the international boundary between the U.S. and Canada.

Several lake sturgeon populations once spawned in the St. Lawrence River and its tributaries (Welsh 2004). Large commercial harvests of lake sturgeon were taken from the St. Lawrence River in the 1800s, and the river sustained commercial harvests into the 1940s and 1950s (Carlson 1995).

Two former known spawning areas for lake sturgeon in the St. Lawrence River, the large rapids at Red Mills and the rapids at Massena, were eliminated by construction of the Massena Dam in 1958 (Zollweg et al. 2003). Lake sturgeon were "moderately common" in the St. Lawrence River from the 1930s through the 1950s, uncommon by the 1960s and rare by the 1970s (Edwards et al. 1989). A small setline fishery for sturgeon persisted into the early 1960s in the upper St. Lawrence River and the small size of many of the fish taken suggested that some reproduction was still taking place (Christie 1973). Between 1880 and 1994 reports of lake sturgeon in the St. Lawrence River were relatively low (Chalupnicki et al. 2011), and only three lake sturgeon catches were recorded from the 1960s to the mid-1990s (Carlson 1995). Spawning was reported in the 1970s and 1980s in the St. Lawrence River near Morristown (at river km 783), American Island (km 792) and downstream of Moses Dam (km 701) (Carlson 1995). Spawning or juveniles were seen in the early 1990s in the St. Lawrence River; the population downstream of Moses Dam might still spawn in the main river and its tributaries (Carlson 1995).

Lake sturgeon in upper Lake St. Francis, the section of the St. Lawrence River between Moses Dam (km 701) and the New York State border (km 687), were still "numerous" and had access to both of the Raquette and St. Regis tributaries (Carlson 1995). Spawning was documented near Ogdensburg bridge in 1994, and lake sturgeon could be found in small numbers in the St. Lawrence River at the Oswegatchie River mouth and at Red Mills (Carlson 1995). Johnson et al. (2006) reported on small numbers of lake sturgeon observed spawning from 1995-1997 on an artificial spawning bed installed on the St. Lawrence River near Ogdensburg, New York; the maximum number of spawners was 9 fish in 1995, 14 fish in 1996, and 8 fish in 1997.

Spawning was documented below the FDR Power Project (Hayes 2000). Holey et al. (2000) reported that the lake sturgeon population in the upper St. Lawrence River numbered in the 100s and it was unknown if there was spawning; and that the lower St. Lawrence River held a small population of unknown size, but with some spawning. Zollweg et al. (2003) reported that the lake sturgeon population was remnant at Thousand Islands, with an annual spawning run in the 100s; remnant with unknown numbers at Lake St. Lawrence; and remnant with unknown numbers at Lake St. Francis.

Today, all the lake sturgeon populations in the St. Lawrence River are now either extirpated, remnant or have undergone a stocking program or similar effort for restoration (Pratt 2008). The upper St. Lawrence River population is now considered to be in a critical conservation state, while the lower St. Lawrence is classified as "cautious"

(Pratt 2008). Farrell et al. (2009) documented the absence of suitable sturgeon spawning sites in the main stem St. Lawrence River above the dam at Massena as well as a lack of sites where spawning bed enhancement could work. Except for a small stretch of river near Waddington, reservoir-like conditions above the dam preclude spawning habitat enhancement as a river-wide solution to population restoration (Farrell et al. 2009).

Lenz (2011) reported lake sturgeon observed during expected spawning season at two artificial spawning beds installed just above and just below Iroquois Dam on the St. Lawrence River, near Waddington, NY. Peak day sturgeon abundance observed at these locations in 2008 was 116 fish; in 2009 was 395 fish; and in 2010 was 261 fish (Lenz 2011). Lenz (2011) estimated a peak abundance of 987 sturgeon in 2009 and 653 sturgeon in 2010. Carlson (2011) noted lake sturgeon spawning in the St. Lawrence River at Massena, Ogdensburg and Iroquois Dam. Klindt and Gordon (2011) collected 124 lake sturgeon in May 2010 at three net sites below the Moses Power Dam. Upstream of the Massena Dam, Klindt and Gordon (2011) collected only 1 lake sturgeon in 2010, in the Thousand Islands/Chippewa Bay area, with a CPUE of 0.01 fish/hr; and only 2 lake sturgeon during 48 net-nights in U.S. waters of the Thousand Islands and Lake St. Lawrence, in the Coles Creek area, known to have high densities of sturgeon.

Lake sturgeon have been stocked in the St. Lawrence River beginning in 1996 (Chalupnicki et al. 2011), but stocking efforts by the New York State Department of Environmental Conservation have not been hugely successful (Heuvel and Edwards 1996; Chalupnicki et al. 2011). In 2013, fingerling lake sturgeon from the Genoa National Fish Hatchery in Wisconsin were stocked by NYSDEC into the St. Lawrence River (Holbrook 2013a). Stocking from St. Lawrence River stock continued through 2016 (NYSDEC 2017).

Oswegatchie River, New York

The Oswegatchie River is a U.S. tributary of the St. Lawrence River

The Oswegatchie River historically supported lake sturgeon spawning up to a natural barrier at river km 94 (Carlson 1995), but access to historic spawning grounds is now blocked by a dam 1.6 km upstream of the river mouth (Auer 1996a). Remnant lake sturgeon populations in the Oswegatchie River are now partitioned into three reaches (Carlson 1995). The population in the lower river, from the mouth to the dam at Ogdensburg (km 0.5), depends on the St. Lawrence River population (Carlson 1995). Spawning was documented near the mouth of the Oswegatchie River in 1931 (Jolliff and Eckert 1971). The other two upstream reaches (separated by a dam at Heuvelton, river km 18, for which fish passage is currently under construction) have had indigenous populations since about 1920 and provided small but important fisheries through about 1960 (Carlson 1995). Spawning was documented below the dam at Heuvelton in 1931 (Jolliff and Eckert 1971). There were former spawning sites and locations of fisheries at Elmdale (km 71) and below Natural Dam at river km 94 (Carlson 1995).

There had been only 3 records of lake sturgeon catches in the Oswegatchie River since the I960s and no sturgeon were located during an extensive field survey in 1991-92 (Carlson 1995). Lake sturgeon were reported infrequently in the Oswegatchie River in the early 1990s, but abundance was believed to be low (Carlson 1995). Holey et al. (2000) reported that the Oswegatchie River population was extirpated. Zollweg et al.

(2003) reported limited or no spawning at the river mouth, and a remnant and reintroduced population in the river. Carlson and Daniels (2004) reported that lake sturgeon had diminished to dangerously low levels in the Oswegatchie River.

Stocking of small and fingerling lake sturgeon into the Oswegatchie River began in 1993 (Chalupnicki et al. 2011; Dittman 2013). Assessments of stocked fish in 1998 and 1999 found some apparently healthy sturgeon staying near the stocking sites and others migrating far downstream (Schlueter 2000). Ripe males were documented in 2010 downstream of major barriers, including near the stocking site downstream of Heuvelton dam, and the females from the earliest years of stocking are approaching the standard age of first reproduction (18-25) for lake sturgeon (Dittman 2013). In 2013, the first wild offspring from a stocked lake sturgeon was documented in the Oswegatchie River (Holbrook 2013b). Stocking from St. Lawrence River stock continued through 2016 (NYSDEC 2017). Young sturgeon spawned by stocked populations were detected in the Oswegatchie River recently (NYSDEC 2017). In 2016, NYSDEC captured 16 suspected wild reproduced sturgeon from the Oswegatchie River above Heuvelton. Fin rays were collected from 12 of these juveniles and sectioned for age calculation; the 12 juveniles were assigned to six year classes between 2002 and 2011 potentially indicating six years of successful wild reproduction (NYSDEC 2017).

Indian River/Black Lake, New York

The Indian River is the largest tributary of the Oswegatchie River.

The Indian River and Black Lake on the lower river (river km 20) are accessible to lake sturgeon from the lower Oswegatchie River downstream of Heuvelton dam (Carlson 1995). Lake sturgeon were caught in Black Lake prior to the 1930s and through the 1950s (Carlson 1995; Zollweg et al. 2003) A lake sturgeon was caught in Indian River at km 33 in 1989 (Carlson 1995). The population is now thought to be extirpated (Holey et al. 2000) or remnant (Zollweg et al. 2003).

A lake sturgeon stocking program was begun in Black Lake in 1995 (Carlson 2005; Chalupnicki et al. 2011; Dittman 2013). A streamside hatchery was built and from 1995-2004, restoration stockings were conducted in Black Lake (NYSDEC). In 2012, a single female lake sturgeon with eggs was captured at one of the natural upstream barriers in the Indian River, 2 km upstream from Black Lake; and the age of first reproduction for the oldest stocked females has been reached (Dittman 2013).

Grasse River, New York

The Grasse River is a U.S. tributary of the St. Lawrence River that flows northeast from the foothills of the Adirondack Mountains.

Lake sturgeon access from the St. Lawrence River to historic spawning grounds in the Grasse River is blocked by Massena Dam, 12 km above the river mouth (Auer 1996a). There are now both resident and migratory lake sturgeon stocks in the Grasse River (Carlson 1995). Sturgeon can move from the St. Lawrence River below Moses Dam at Massena into the lower Grasse River up to the first barrier at Massena at river km 12 (Carlson 1995). Sturgeon may be able to swim over this dam under certain high water conditions, so the remaining section of the lower river from Massena upstream to the Madrid Dam at km 34 may also contain both resident and migratory fish (Carlson 1995).

The upstream limit of the historic range of lake sturgeon in the Grasse River is uncertain; there were only minor rapids below a natural barrier at Pyrites (km 68), and a former dam at Madrid (removed in 1940) allowed sturgeon passage (Carlson 1995). The Grasse River from Madrid to Pyrites may have had a relict population historically, but there are no reports of lake sturgeon in the apparently favorable river rapids near Canton at km 58 (Carlson 1995).

There was a small commercial fishery for lake sturgeon in the Grasse River through the late 1950s (Carlson 1995). Spawning was reported below the dam at Massena (Jolliff and Eckert 1971). Spawning or juveniles were seen in the early 1990s in the Grasse River, with spawning documented at Madrid in 1992 (Carlson 1995).

Today lake sturgeon are relatively rare in the Grasse River (Carlson 1995). The natural population was thought to be small (Holey et al. 2000), but some recruitment was occurring and there were more than 20 miles of river available to sustain the resident population (Zollweg et al. 2003).

The Grasse River population has been reconnected from the St. Lawrence River to the dam in Madrid by a breach in the weir at Massena (NYSDEC 2017). Some successful spawning activity has been documented recently in the Grasse River (Trested 2010; Trested and Isley 2011; Trested et al. 2011; Chalupnicki et al. 2011), with an estimated population of 739 fish of all ages, from the confluence with Lake St. Francis upstream to Madrid Dam at km 51 (Trested 2010; Trested and Isley 2011; Trested et al. 2011). Abundance of lake sturgeon in the Grasse River upstream from Madrid Dam is unknown (Trested 2010). No lake sturgeon older than 32 years were found in the Grasse River, with most fish between 3 and 14 years of age (Trested 2010). Trested (2010) estimated a high annual mortality rate of 16.8%.

Some stocking of lake sturgeon seems to have occurred in the Grasse River (Trested 2010). Stocking occurred in 1993 (NYSDEC 2017).

<u>Raquette River, New York</u>

The Raquette River is a U.S. tributary of the St. Lawrence River.

The Raquette River historically had substantial habitat available to lake sturgeon, but available sections were noted to remain largely uninhabited (Greeley 1934; Carlson 1995). Lake sturgeon access to possible historic spawning grounds in the Raquette River is blocked by a dam at Raymondville, 30 km above the river mouth (Auer 1996a). Carlson (1995) noted that rapids at Raymondville may have been a historic natural barrier before the dam.

A spawning run of lake sturgeon was documented at Raymondville in 1994, but documentation of a resident population in the Raquette River is lacking (Carlson 1995). Holey et al. (2000) and Zollweg et al. (2003) reported on a remnant population with unknown numbers of fish, and unknown if there was spawning. There is suitable sturgeon spawning habitat in the lower reaches of the Raquette River (NYSDEC 2014). The Raquette River has some indication of potential natural reproduction by direct observation of spawning fish, or capture of fish too young to have been stocked (NYSDEC 2017).

Stocking of lake sturgeon began in the Raquette River in 2004 (Chalupnicki et al. 2011). Fingerling lake sturgeon from the Genoa National Fish Hatchery in Wisconsin were stocked by the NYSDEC into the Raquette River in 2013 (Holbrook 2013a). Stocking from St. Lawrence River stock continued through 2016 (NYSDEC 2017).

St. Regis River, New York

The St. Regis River is a U.S. tributary of the St. Lawrence River.

The St. Regis River historically had substantial habitat available to lake sturgeon up to Brasher Falls, a natural barrier at river km 32 (Carlson 1995). Construction of Hogansburg Dam and hydropower station, built 3 km from the river mouth in the 1930s, blocked lake sturgeon access to historic spawning grounds (Greeley 1934; Carlson 1995; Auer 1996a). Hogansburg dam was removed in 2016, reconnecting the St. Regis River with the St. Lawrence up to Brasher Falls.

The lower 3 km of the St. Regis River was believed to be a former spawning area, but there are no records prior to the 1900s to confirm lake sturgeon use of this area (Hazzard 1931; Carlson 1995). No lake sturgeon were observed from the upper end of that reach from 1969-1990 (Carlson 1995). Lake sturgeon were reported infrequently in the early 1990s in the St. Regis River (Carlson 1995). Holey et al. (2000) and Zollweg et al. (2003) reported a remnant lake sturgeon population in the St. Regis River, with unknown numbers of fish and unknown if there was spawning.

Lake sturgeon have been stocked in the St. Regis River since 1998 (Carlson and Daniels 2004; Chalupnicki et al. 2011). Sampling by USGS in 2004 and 2005 captured 121 juvenile sturgeon that represented all the stocked year classes of the 4,977 fingerlings stocked from 1998 to 2004 in the St. Regis River (NYSDEC 2017). Stocked juvenile sturgeon are successfully using about 32 km of higher-gradient accessible habitat (Dittman 2008). Fingerling lake sturgeon from the Genoa National Fish Hatchery in Wisconsin were stocked by NYSDEC into the St. Regis River in 2013 (Holbrook 2013a). Stocking from St. Lawrence River stock continued through 2016 (NYSDEC 2017).

Lake Champlain Basin, New York/Vermont

Lake Champlain is part of the Lakes to Locks Passage which connects to the Erie Canal via the Champlain Canal. Lake Champlain is connected to the St. Lawrence River via the Richelieu River in Quebec.

Lake Champlain

According to local Abenaki, lake sturgeon have long been prized as an important food resource by the native American settlers along the shores of Lake Champlain (Donelson et al. 2010). Lake Champlain historically supported a small, but stable, lake sturgeon population (Moreau and Parrish 1994). Moreau and Parrish (1994) estimated an historic population of 3,000 adult sturgeon in Lake Champlain, based on fishery data. Large commercial harvests of lake sturgeon were taken from the lake in the 1800s (Carlson 1995) and into and the early 1900s, taking from 50 to 200 sturgeon annually (Mackenzie 2011). Lake sturgeon were fished with gill nets in Lake Champlain rivers until 1888 (Brainerd and Atherton 1890). Lake sturgeon harvests prior to 1913 averaged over 100 fish annually, but declined sharply to less than 15 fish per year in the 1950s and 1960s (Halnon 1963).The lake sturgeon populations of Lake Champlain were not exploited as intensely as some of the other sturgeon populations and managed to sustain harvests into the 1940s and 1950s (Carlson 1995, p. 40). Commercial fishery catches in Lake Champlain near the Missisquoi River and Grand Isle ranged from 1 to 7 tonne/year from 1900-1950 (Carlson 1995; Marsden and Langdon 2012). Harvest declined rapidly due to overfishing and habitat loss in the rivers that were used as spawning and nursery grounds, and the fishery was closed in 1967 (Mackenzie 2011). The population never recovered (Mackenzie 2011).

The Vermont Department of Fish and Wildlife recorded lake sturgeon sightings or catches of up to 12 sturgeon annually between 1980 and 1993, but most years sightings were considerably less (Moreau and Parrish 1994). Lake sturgeon were reported infrequently in Lake Champlain in the early 1990s (Carlson 1995). Holey et al. (2000) and Zollweg et al. (2003) reported a remnant lake sturgeon population remained in Lake Champlain, with unknown numbers of fish and unknown whether there was spawning. McKenzie (2008) reported the Lake Champlain population has been diminishing. Moreau et al. (1993), Carlson (2011), and Marsden and Langdon (2012) noted occasional reports of lake sturgeon within Lake Champlain, with the species thought to spawn in lake tributaries in Vermont. Mackenzie (2011) documented recent spawning activity in 3 of 4 historic spawning tributaries to Lake Champlain and movement of individual sturgeon between spawning sites.

<u>Missisquoi River, Vermont</u>

The Missisquoi River is a tributary of Lake Champlain in Vermont. The river is 74 miles long in Vermont and contains seven dams.

Historic lake sturgeon spawning grounds were found in the Missisquoi River (Stone 1901; Carlson 1995; Mackenzie 2011). Lake sturgeon formerly spawned at the base of Highgate Falls, but since the installation of Swanton Dam in the early 1900s, sturgeon were limited to spawning in rapids in an 8-mile reach below the dam (Moreau and Parrish 1994; Lyttle 2008). The former sturgeon habitat blocked by Swanton Dam had 300 times more suitable spawning habitat than was available to lake sturgeon below the dam (Lyttle 2008). Lake sturgeon passage through Swanton Dam on the Missisquoi River has recently been restored.

Mackenzie (2011) was unable to capture any sturgeon during 2001 and 2003 surveys of historic spawning sites in the Missisquoi River, however sampling for sturgeon eggs between 2003 and 2008 resulted in sturgeon eggs collected in 3 of the 4 sampling years in the Missisquoi River. Mackenzie (2011) also sampled for larval lake sturgeon in the Missisquoi River in 2008, but was unable to detect any larval sturgeon. Collection of eggs indicates that lake sturgeon are spawning in the Missisquoi River (Marsden et al. 2010).

<u>Lamoille River, Vermont</u>

The Lamoille River is a tributary of Lake Champlain in Vermont.

Historically, lake sturgeon spawned in the Lamoille River (Stone 1901; Carlson 1995; Mackenzie 2011). Spawning was formerly known from the Sturgeon Hole below Woods

Falls (Stone 1901; Carter 1904), but since the installation of Peterson Darn in 1948, potential spawning habitat had been limited to the rapids below the dam (Moreau and Parrish 1994). Lake sturgeon passage through Peterson Dam has recently been restored.

Mackenzie (2011) surveyed historic spawning sites in the Lamoille River from 1998 to 2002, and caught very small numbers of sturgeon each year. Mackenzie (2011) also sampled the Lamoille River for sturgeon eggs and larvae between 2003 and 2008, successfully collecting eggs in 3 of the 5 sampling years, and collecting larval lake sturgeon in 2005. Collection of eggs and larvae indicates that lake sturgeon are spawning in the Lamoille River (Marsden et al. 2010).

<u>Winooski River, Vermont</u>

The Winooski River is a tributary of Lake Champlain in Vermont.

Historic lake sturgeon spawning grounds were found in the Winooski River (Stone 1901; Carlson 1995; Mackenzie 2011). Winooski Falls, located 15 km from Lake Champlain, limited sturgeon spawning migrations on the Winooski River before a dam was installed (Moreau and Parrish 1994).

Mackenzie (2011) caught very small numbers of lake sturgeon each year during 1998 to 2002 surveys of historic spawning sites in the Winooski River. Mackenzie (2011) also collected sturgeon eggs in the Winooski River all 5 years during sampling from 2003-2008, and collected sturgeon larvae during both years of sampling from 2004-2005. Collection of eggs and larvae indicates that lake sturgeon are spawning in the Winooski River (Marsden et al. 2010). In 2012 anglers reported catching more than 12 sturgeon in the Winooski River (VTFW 2016). In May 2015, the Vermont Department of Fish and Wildlife collected 16 sturgeon in the Winooski River, ranging in length from 48 to 55 inches and weighing between 20 and 40 pounds (VFW).

<u>Otter Creek, Vermont</u>

Otter Creek is a tributary of Lake Champlain in Vermont.

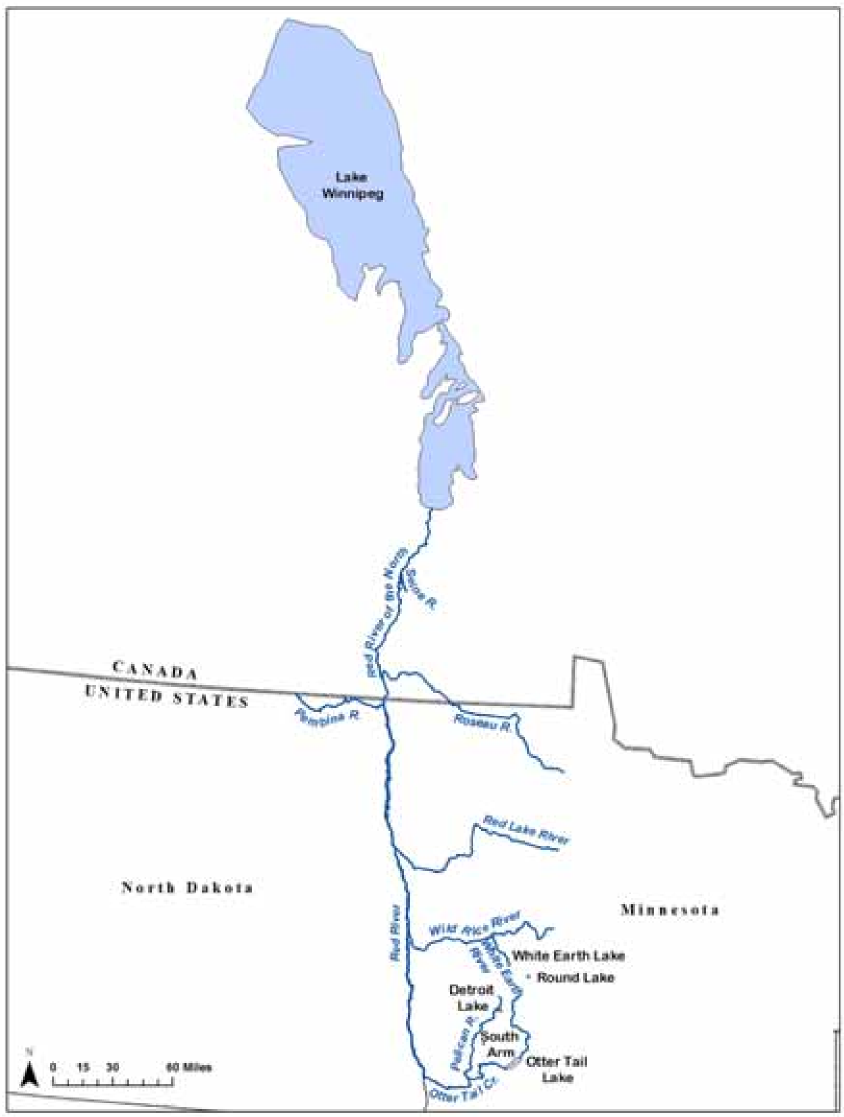
Historic spawning grounds for lake sturgeon were found in Otter Creek (Stone 1901; Carlson 1995; Mackenzie 2011). Before the construction of Vergennes Dam on Otter Creek, located 12.5 km from Lake Champlain, the falls at Vergennes once limited spawning migrations (Moreau and Parrish 1994).

Mackenzie (2011) sampled for sturgeon eggs in Otter Creek between 2003 and 2008, and sturgeon larvae in 2005, but was unable to detect any sturgeon eggs or larval sturgeon.

Northwestern Minnesota

Basin-wide Distribution and Abundance

In Northwestern Minnesota, formerly abundant populations in the Red River and many of its tributaries have been largely extirpated. Stocking of lake sturgeon is occurring in the Red River in Minnesota and in the Assiniboine River in Canada, but it will likely take another decade until reproducing populations are established. In the Rainy River/Lake of the Woods system, the lake sturgeon population was estimated at 60,000 sturgeon longer than 40 inches in 2004. Complete population estimates are not available for Rainy Lake sturgeon, which mix with the lower Seine River population.



The Red River and tributaries in Northern Minnesota with former and current lake sturgeon spawning populations

Red River, Minnesota

The Red River flows along the Minnesota/North Dakota border north into Lake Winnipeg in Manitoba, Canada.

Historical accounts suggest that lake sturgeon were abundant in the Red River basin until the late 1800s, but by the early to mid-1900s had been largely extirpated by overexploitation and construction of dams that blocked their migration routes (MNDNR 2002; Aaland et al. 2005). Over 500 dams have been built in the Red River basin since the late 1800s and most U.S. tributaries that had suitable lake sturgeon spawning habitat had been blocked by dams by the 1870s (Aaland et al. 2005). Lake sturgeon were historically found in many Red River tributaries including Red Lake River, Otter Tail River and Otter Tail Lake, Round Lake, White Earth River and White Earth Lake, Detroit Lake and the upper Pelican River system, and the Roseau River (MNDNR 2002). In the early 1800s, juvenile lake sturgeon as well as adults during likely spawning migration were caught on the Pembrina River tributary at its confluence with the Red River, on the North Dakota/Minnesota border (Aaland et al. 2005). Historically, the confluence of the Red Lake River and Clearwater River tributaries of the Red River in Minnesota was famous for lake sturgeon fishing in the spring, and “great numbers” of lake sturgeon formerly passed the confluence of the Red River and the Red Lake River tributary in Grand Forks, South Dakota in the spring (Aaland et al. 2005).

In the Canadian component of the Red-Assiniboine Rivers/Lake Winnipeg sturgeon, very large populations that formerly occurred in Lake Winnipeg and its tributary rivers were depleted by commercial exploitation in the early 1900s (COSEWIC 2006). By the early 2000s, there was no evidence of naturally reproducing populations in the major watersheds of the Assiniboine or Red Rivers, and lake sturgeon were extremely rare in the Red River from Lake Winnipeg to the American border (COSEWIC 2006). A number of smaller tributaries to Lake Winnipeg (Pigeon, Bloodvein, Poplar and Berens rivers) supported lake sturgeon, but spawning females were unlikely to exceed 100 annually in any component (COSEWIC 2006). Canada designated the Red-Assiniboine Rivers/Lake Winnipeg population of lake sturgeon as “endangered” in 2006 (COSEWIC 2006).

Although there have been occasional, unconfirmed reports of lake sturgeon being caught recently in the Red River in Minnesota, there is little chance that this population could recover on its own (MNDNR 2002). Since 1994, 5 of the 8 dams on the mainstem of the Red River in the U.S. have been modified to allow sturgeon passage, and another 19 dams have been modified or removed on tributaries (Abraham and Kallak 2008); there are plans to remove or modify many more dams (MNDNR 2002).

In 2002, the Minnesota Department of Natural Resources (MNDNR) began implementing a 20-year plan to restore lake sturgeon in the Red River basin (MNDNR 2002). Lake sturgeon fry and fingerlings from the Rainy River (COSEWIC 2006) are stocked into Red River basin rivers and lakes, with a goal of reestablishing a naturally reproducing population over the next 20 to 30 years. The MNDNR and the White Earth Ojibwe Nation have been stocking about 20,000 fingerlings annually into Red River lakes and tributaries in the U.S.; MNDNR has also stocked an average of over 150,000 fry each year (MNDNR 2002; Aadland et al. 2005; Abraham and Kallak 2008).

Rainy Lake/Rainy River/Lake of the Woods, Minnesota

Rainy Lake is a freshwater lake located on the Minnesota-Ontario border, and part of the Winnipeg-Nelson drainage system that flows northwards into Hudson Bay. Rainy Lake consists of three main basins: the North Arm, Redgut Bay, and the South Arm. The North Arm and Redgut Bay are both located entirely in Canada; the South Arm extends for 56 km along the border of the United States and Canada. Lake sturgeon in Rainy Lake have been segregated from upstream Namakan Lake and downstream Lake of the Woods/Rainy River system sturgeon populations by dams constructed on the outlets of Rainy and Namakan lakes early in the 20th century (Adams et al. 2006a).

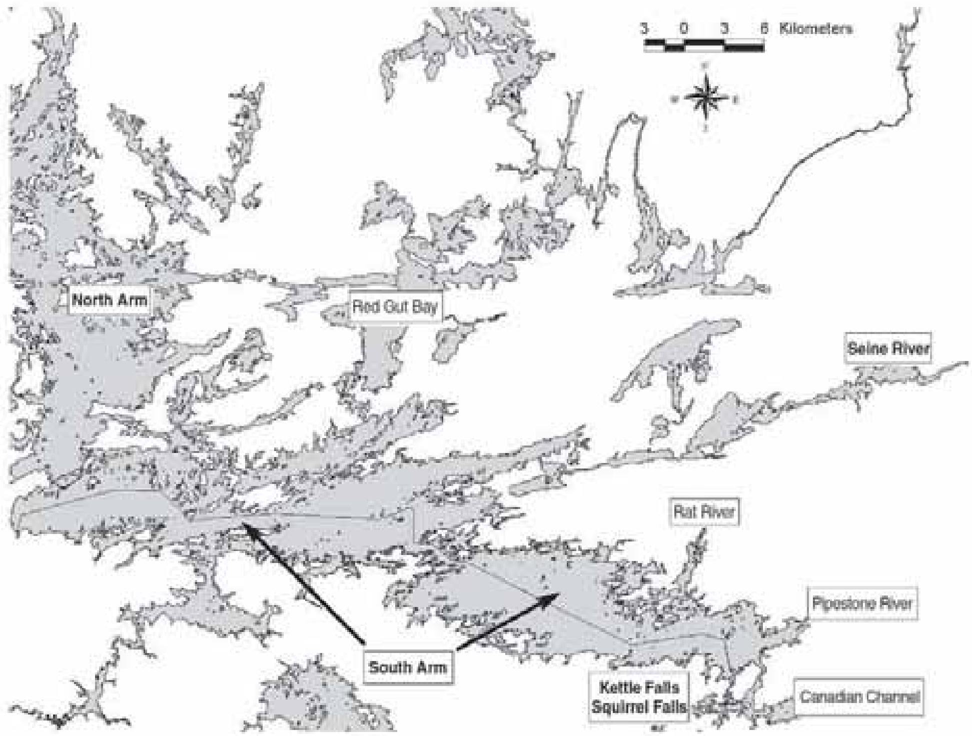


FIGURE 1. Rainy Lake, Minnesota and Ontario. The line across the South Arm indicates the border between Canada and the United States.

Rainy Lake map from Adams et al. (2006)

Lake of the Woods and the Rainy River are also part of the Winnipeg-Nelson River system. Lake of the Woods is situated on the Canada-United States border, where the state of Minnesota and provinces of Ontario and Manitoba meet. Lake sturgeon are largely restricted to the southern half of Lake of the Woods, concentrated in the Big Traverse basin, and the Rainy River. The lake covers about 385,000 ha, two-thirds of which lies in Canada. The Rainy River enters at the extreme southeast comer of Lake of the Woods and is the largest tributary to the lake. The river flows approximately 140 km between Rainy Lake and Lake of the Woods, and is controlled at the outflow from Rainy Lake by a hydroelectric dam built in 1909. Prior to the dam's construction, a waterfall provided a natural barrier to upstream fish migration. Major tributaries flowing into the Rainy River include the Big Fork, Little Fork, Black, and Rapid rivers on the Minnesota side and the Pinewood, Sturgeon, and La Vallee rivers in Ontario.

Historically, lake sturgeon were abundant in Lake of the Woods and the Rainy River (MNDNR 2015), and an important cultural and economic resource in the Rainy Lake area (Adams et al. 2006a), but intense commercial harvest during the late 1800s and early 1900s decimated the population (MNDNR 2015a). After the cessation of commercial fisheries, the population in Rainy River, the main spawning area, was unable to rebound due to water pollution (MNDNR 2015a). After the passage of the Clean Water Act, the sturgeon population was able to grow. Rusak and Mosindy (1997) identified two discrete populations of lake sturgeon in this watershed, a "river" population which consistently inhabited Rainy River during the winter months, and a "lake" population which spawned later and initiated extensive spring and summer movements.

Population estimates of sturgeon longer than 40 inches in the Lake of the Woods-Rainy River system were made in 1990 (~16,000 fish) and 2004 (~60,000 fish) (Stewig 2005; MNDNR 2015a).

Rainy River and the southern half of Lake of the Woods (from Rusak and Mosindy 1997)

Rainy Lake sturgeon stock assessment data are only available for the South Arm; the other two lake basins (North Arm and Redgut Bay) have not been assessed (COSEWIC 2006). Lake sturgeon abundance in the South Arm may have been increasing by the early 2000s, but a full age structure had not been re-established and recruitment was still variable (COSEWIC 2006). The Rainy Lake population mixes with the lower Seine River population, and discreteness of the spawning components is unknown (COSEWIC 2006). Only one site within Rainy Lake, at Squirrel Falls, has been confirmed as lake sturgeon spawning habitat, with collection of eggs and telemetry data indicating high sturgeon utilization of the Squirrel Falls area (Adams et al. 2006a). Kettle Falls in the U.S., as well as the Pipestone and Rat rivers in Canada may also be potential spawning grounds, based on seasonal aggregations of adult sturgeon (Adams et al. 2006a). Movement of lake sturgeon between the Seine River and the South Arm of Rainy Lake indicates the likelihood of one integrated population on the east end of the South Arm (Adams et al. 2006a). Adams et al. (2006b) caught 322 individual lake sturgeon in Rainy Lake from 2002-2004.

Mississippi River Basin

The Mississippi River basin with major tributaries

Upper Mississippi River Basin

Basin-wide Distribution and Abundance

Historically, lake sturgeon were "extremely plentiful" in the upper Mississippi River, but now are rare throughout the upper Mississippi River basin, with small populations remaining in the Chippewa, Flambeau, Fox, Kettle, Manitowish, Namekagon, Rock, St. Croix, Wisconsin and Yellow river tributaries. There are no known recent records from the Baraboo, Illinois, Minnesota or Snake river tributaries.

Restoration stocking from appropriate in-basin populations has begun in the upper Mississippi River and the Flambeau, Fox, Manitowish, Namekagon, Salt, Wisconsin and Yellow river tributaries, but there has been no known reproduction.

Upper Mississippi River and tributary areas with former and current lake sturgeon spawning populations

<u>Upper Mississippi River</u>

Historically, lake sturgeon were extremely plentiful in the upper Mississippi River, with reports of the species as early as 1673 and 1767 (Carlander 1954; Carlson and Pflieger 1981; Pflieger 1997). Populations declined drastically due to overfishing in the early 1900s (Carlson and Pflieger 1981; Pflieger 1997). Commercial lake sturgeon harvests in the upper Mississippi River between St. Paul, Minnesota and Cairo, Illinois declined 97% between 1894 and 1922, dropping from 113,000 kg (249,000 pounds) to 3,000 kg (Carlander 1954; Knights et al. 2002). At such low levels, these small populations deteriorated to a harvest of zero by 1931 (Carlander 1954; Ferguson and Duckworth 1997; Knights et al. 2002). In the early days lake sturgeon were taken commercially mainly for their eggs (Carlander 1954). Lake sturgeon occurred in the upper Mississippi River up to St. Anthony Falls, Minnesota (Eddy 1945), the only natural major waterfall on the upper Mississippi River.

Sturgeon migration is now disrupted by a series of low-head navigation dams on the mainstem of the upper Mississippi River, and high-head dams on tributaries of upper Mississippi River block historical migrations and isolate groups of sturgeon above and below these dams (Knights et al. 2002). Lock and Dam 19 at Keokuk, Iowa on the upper Mississippi, is a nearly complete barrier because of its hydropower function (Wilcox, et al. 2004).

A large (76”) sturgeon was taken from the upper Mississippi River at Muscatine, Iowa in 1931 (Carlander 1954). There is little information on the current status of lake sturgeon in the upper Mississippi River, but the species is now considered rare due to historic overharvest, pollution and dam construction (Becker 1983; Pitlo et al. 1995; Knights et al. 2002; IADNR 2014). Lake sturgeon were observed in the upper Mississippi River in Illinois (Nyboer et al. 2006).

Restoration stocking (with lake sturgeon of Wisconsin origin) began in the upper Mississippi River in 1984; with release sites at Lagrange, Shanks Conservation Area, and Louisiana, Missouri (MDOC 2007). Stocked lake sturgeon began to be encountered on the Mississippi River by anglers and biologists from Pool 20 below Keokuk, Iowa downstream to Chester, Illinois, and in some of the larger tributaries in Missouri, Nebraska, and Illinois; but as of 2007 there was no known reproduction and populations were far from self-sustaining (MDOC 2007). In the last decade population increases of lake sturgeon have been observed, with Buszkiewicz et al. (2016) documenting the first spawning of lake sturgeon in the upper Mississippi River in Missouri. Recent lake sturgeon catch data indicate that approximately 11 percent of the stocked Mississippi River sturgeon population in Missouri are reproductively mature and telemetry data confirms that the greatest movement by adult lake sturgeon occurs during spring, which suggests spawning behavior (Buszkiewicz et al. 2016). Buszkiewicz et al. (2016) documented lake sturgeon embryos and emergent fry larvae below Melvin Price Locks and Dam 26 in the Upper Mississippi River near St. Louis, Missouri.

Minnesota River, Minnesota

Lake sturgeon were formerly found in the Minnesota River, a tributary of the upper Mississippi River in Minnesota (Eddy 1945).

Minnesota and South Dakota are reintroducing lake sturgeon to Big Stone Reservoir, at the upper end of the Minnesota River (J. Lott, pers. comm., 2018).

St. Croix River System, Minnesota/Wisconsin

The St. Croix River is a tributary of the upper Mississippi River and the upper river forms the border between Minnesota and Wisconsin (Wendel and Frank 2012).

The species was documented in the St. Croix River by Eddy (1945). Becker (1983) noted that lake sturgeon were formerly “common” in the St. Croix River, occurring up to the Gordon Dam at river km 249.

The Minnesota Department of Natural Resources tagged 39 lake sturgeon from 1992-2003 in the St. Croix River (MNDNR 2014a). Although the Wisconsin Department of Natural Resources listed lake sturgeon as a “common species” in their 2000 report (WDNR 2000), Wendel and Frank (2012) examined 70 river miles and found that annual populations of lake sturgeon in the St. Croix River measuring > 21 inches were estimated to be between 284 and 947 fish/year from 2004-2010. It should be noted that a substantial portion of the population estimate was comprised of juvenile fish. The highest estimate was in 2006, and by 2010 the population was down to a mere 530 fish (Wendel and Frank 2012). These population levels are below the lower limits for a self-sustaining population (Welsh et al. 2010; Wendel and Frank 2012) and an estimated survival rate of only 59% does not provide much hope for population recovery (Wendel and Frank 2012). Wendel and Frank (2012) also found that St. Croix River lake sturgeon were highly catchable, recommending that the lake sturgeon recreational fishery remain closed to prevent rapid population decline. Lake sturgeon are still present in the 32 km of the upper St. Croix River from its confluence with the Namekagon River to the Gordon Dam, but abundance has declined significantly since the 1960s (Kampa et al. 2014a).

Lake sturgeon from Yellow Lake (in the Yellow River tributary of the St. Croix River) are apparently being raised in a hatchery for stocking in the upper St. Croix River above Gordon Dam (DTO 2002).

Snake River, Wisconsin

Lake sturgeon formerly occurred in the Snake River tributary of the St. Croix River in Minnesota, between McGrath, Minnesota and the confluence with the St. Croix River (Reedstrom 1964).

Kettle River, Minnesota

The Kettle River is a tributary of the St. Croix River in eastern Minnesota.

From 1992-2003, the Minnesota Department of Natural Resources tagged 439 lake sturgeon in the Kettle River (MNDNR 2014a). The Kettle River has a small, year-round, resident population of lake sturgeon, estimated at 97 fish of all ages (not spawning fish) in 1994; and 346 fish by 2002 (Borkholder et al. 2002; MNDNR 2014a). Sandstone Dam, built in 1908 at river km 22, formerly blocked lake sturgeon migration upstream (Borkholder et al. 2002). Sandstone Dam was removed in 1995, potentially restoring spawning habitat and reconnecting a historically important tributary on the upper river (Abraham and Kallak 2008). However, after dam removal, years of accumulated sediment from behind the dam washed downstream, covering known sturgeon spawning sites and filling in important deep pool habitats in the river (Abraham and Kallak 2008). Sampling in 2003 revealed that sturgeon are now migrating upstream of the former dam site (MNDNR 2014a). Although a recreational lake sturgeon fishery was closed and Sandstone Dam was removed, Dieterman et al. (2010) found that Kettle River lake sturgeon are struggling to maintain their numbers, with annual population estimates (not spawners) ranging from about 130 fish to almost 300 fish, and annual survival estimated at 80%. The lake sturgeon population in the Kettle River is a resident, year-round population, and the fish do not seem to migrate downstream into the St. Croix River or mix with adjacent populations (Borkholder et al. 2002; MNDNR 2014a).

Namekagon River, Wisconsin

The Namekagon River is a tributary of the St. Croix River in Wisconsin.

Trego Dam, constructed in 1927 at river km 50, blocks lake sturgeon access to upstream habitat in the Namekagon River (Kampa et al. 2014a, 2014b). Becker (1983) noted that lake sturgeon were “common” in the Namekagon River below Trego Dam. Lake sturgeon are still present in the Namekagon River from its confluence with the St. Croix River to Trego Dam, but abundance has declined significantly since the 1960s (Kampa et al. 2014a). Recent annual electrofishing catch of lake sturgeon was only 6% of the catch during the 1960s on a 32 km reach of the Namekagon River, and size structure showed that recruitment was significantly higher during the 1960s in the Namekagon

River (Kampa et al. 2014a). From 2006-2013, 34 lake sturgeon from 6 year classes were observed or captured upstream of the Trego Dam, ranging from 32 to 112 cm total length (Kampa et al. 2014b).

The Wisconsin Department of Natural Resources (WDNR) began stocking hatchery-reared lake sturgeon in the Namekagon River below Trego Dam in 1993 from a genetically appropriate source above the dam, and protecting stocked fish from harvest with a closed lake sturgeon fishing season in the Trego Flowage and the Namekagon River upstream from the flowage (Kampa et al. 2014b). WDNR is considering fish passage options at the Trego Dam to allow upstream passage of naturally recruited fish (Kampa et al. 2014b).

Yellow River/Yellow Lake, Wisconsin

The Yellow River is a tributary of the St. Croix River in Wisconsin. A water control structure on the Danbury Flowage maintains Yellow Lake, which the Yellow River flows into.

The lake sturgeon population of Yellow Lake has been isolated from the St. Croix River population since a dam was built on the Danbury Flowage in the 1930s (Wendell and Damman 2011).

Wisconsin's record hook and line caught lake sturgeon (which weighed over 170 lbs) was caught in 1979 in the Yellow River, drawing angling attention to and decimating this population over time. In 1986 the population estimate was 288 fish $\geq$45 inches (Wendell and Damman 2011). Johannes (1988) found that the population was nowhere near recovery, with most fish sampled less than 20 years of age.

By 1995, management was needed to help the population recover and the Wisconsin Department of Natural Resources stocked 10,000 fry and over 13,000 fingerlings in to the Yellow River, and similar rearing and stocking efforts continue today (WDNR 2000). By 2008, the abundance of lake sturgeon $\geq$45 inches was estimated to have increased to 1,628 fish, but biologists warned that this number should not be used in making management decisions due to concerns with recapture methods (Wendel and Damman 2011). There was a strong base of middle-aged fish, but only 4 sturgeon were found to be over 40 years old (Wendel and Damman 2011). Further monitoring was recommend for the population, and maintaining harvest limits, as well as consideration of reconnecting the Yellow River to the St. Croix River to ensure sustainable genetic diversity and connect critical habitat (Wendel and Damman 2011).

Chippewa River, Wisconsin

The Chippewa River is a tributary of the upper Mississippi River.

Lake sturgeon were at one time reported as "common" in the Chippewa River (Becker 1983; WDNR 2000).

Lake sturgeon are found in both the East Fork and West Fork of the Chippewa River (DTO 2002; Galarowicz 2003). Holey et al. (2000) reported that the Chippewa River lake sturgeon population was thought to be small, with unknown numbers. Seasonal fish passage for lake sturgeon has been established recently at a small hydroelectric facility on the East Fork of the Chippewa River (Kampa et al. 2014a).

Flambeau River, Wisconsin

The Flambeau River is one of the major tributaries of the Chippewa River in Wisconsin.

Lake sturgeon were at one time reported as “common” in the Flambeau River (Becker 1983; WDNR 2000). A former major sturgeon spawning site at the confluence of the Turtle and Flambeau rivers was destroyed in 1926 by construction of a dam on the Flambeau River that created the Turtle-Flambeau Flowage, a lake impoundment of approximately 14,000 acres (WNRM 2009).

Lake sturgeon currently occur in both the North Fork and South Fork of the Flambeau River (DTO 2002; Galarowicz 2003). Though lake sturgeon were still present in 2009 in the Flowage lake and two sites were identified where adult sturgeon were found spawning, it was thought that there is no successful natural reproduction in the flowage and no young fish to rebuild the population (WNRM 2009).There are reports of a “very healthy” lake sturgeon fishery in the North Fork Flambeau River system, both above and below Park Falls, with significant fishing pressure each fall (15-30 fish in the 50-55” range taken annually), and with sturgeon also occasionally taken in the South Fork and Butternut Lake (DTO 2002).

Since 1993, a restoration stocking program has captured adult lake sturgeon from the Flambeau River to propagate fingerlings and fry that are restocked into the Flambeau Flowage system (WNRM 2009).

Mantowish River, Wisconsin

The Mantowish River is a tributary of the Flambeau River in Wisconsin.

A 1990 survey of the Manitowish River documented a small, remnant lake sturgeon population (WNRM 2009). All sturgeon captured during that survey were extremely large, old fish, likely born before the Turtle-Flambeau Flowage was created in 1926 (WNRM 2009). Limited spawning by lake sturgeon has been documented in the Manitowish River (Scheidegger 2000).

Brood stock of lake sturgeon were collected from the Manitowish River in 1998 and 24,000 fingerlings were stocked back into the river (Scheidegger 2000). Attempts are also being made to collect and spawn lake sturgeon from the North Fork of the Flambeau River and stock the fry and fingerlings into the Manitowish River (Scheidegger 2000).

Wisconsin River, Wisconsin

The Wisconsin River is a tributary of the upper Mississippi River in southern Wisconsin.

Historical records of lake sturgeon in the Wisconsin River exist upstream to the Castle Rock Flowage (river mile 268), in Adams County, Wisconsin (Scheidegger 2000). Lake sturgeon were formerly “common” in Lake Wisconsin (Becker 1983), a downstream reservoir on the Wisconsin River created by construction of a dam at Prairie du Sac, Wisconsin. Construction of Lake Wisconsin ended the Fox-Wisconsin Waterway connection to the Mississippi River. There are now 26 dams on the Wisconsin River, blocking upstream sturgeon passage. A FERC relicensing process will provide future fish passage for lake sturgeon past the Prairie du Sac Dam (Kampa et al. 2014a).

Lake sturgeon are now considered uncommon to rare in the lower Wisconsin River and are probably extirpated from the middle Wisconsin River in Wood, Portage, and Marathon counties (Becker 1983; WDNR 2000).

A restoration stocking program has begun, with juvenile sturgeon transferred from Lake Wisconsin to the lower Wisconsin River from 1991-1992; and hatchery-reared fingerlings from below the Wisconsin Dells Dam re-stocked in the upper Wisconsin River below the Du Bay Dam from 1997-2002 (DTO 2002). The Wisconsin Department of Natural Resources began augmenting the Wisconsin River lake sturgeon population with stockings of juvenile lake sturgeon in 2010 and 2012 (WDNR 2013). Annual sampling of the Wisconsin River lake sturgeon population since 2006 caught between 40-100 stocked fish each year that range from 20-44 inches (WNMR 2009).

Baraboo River, Wisconsin

The Baraboo River is a tributary of the Wisconsin River in south-central Wisconsin.

Lake sturgeon historically utilized upper portions of the Baraboo River for spawning, prior to the placement of dams (WDNR 2013). Lake sturgeon were extirpated from the Baraboo River tributary (Becker 1983; WDNR 2013).

Removal of 7 dams from the Baraboo River was completed by 2001, which will potentially allow lake sturgeon to again move into the upper reaches of the Baraboo River for spawning (WDNR 2013).

Des Moines River, Iowa

The Des Moines River is a tributary of the upper Mississippi River in Iowa.

A lake sturgeon specimen was collected recently from the Des Moines River tributary, one of the first documented occurrences of this species in Iowa's interior waters (IADNR 2014).

Maquoketa River, Iowa

The Maquoketa River is a tributary of the upper Mississippi River in Iowa.

A lake sturgeon specimen was collected recently from the Maquoketa River, one the first documented occurrences of this species in Iowa's interior waters (IADNR 2014).

Rock River, Illinois

The Rock River is a tributary of the upper Mississippi River in Wisconsin and Illinois

Lake sturgeon were observed recently in the Rock River in Illinois (Nyboer et al. 2006).

Salt River, Missouri

The Salt River is a tributary of the upper Mississippi River in eastern Missouri.

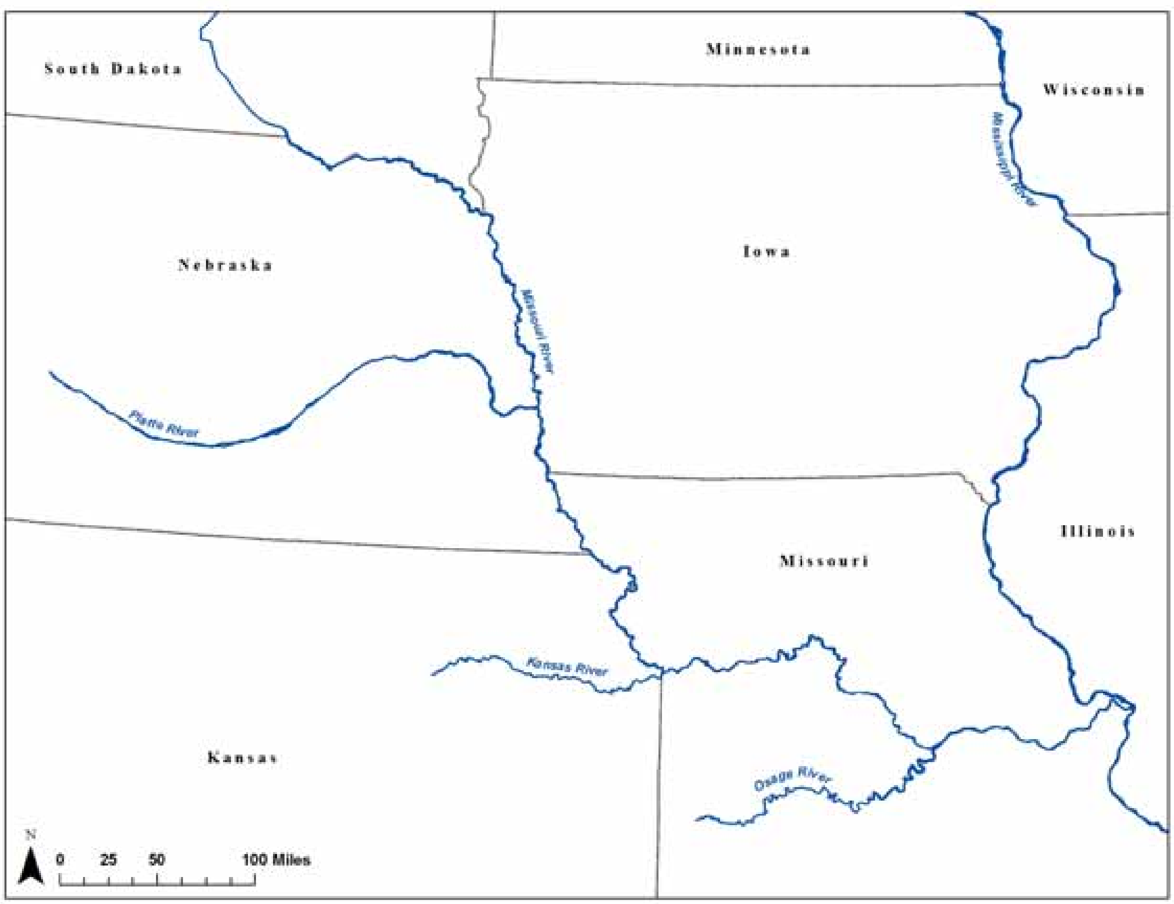
Lake sturgeon of Wisconsin origin have been stocked recently into Mark Twain Lake on the Salt River tributary (MDOC 2007). Lake sturgeon stocked prior to 2002 came from the Wolf River in Wisconsin, in the Lake Winnebago system (Great Lakes Basin). Beginning in 2002, the egg source has been the Wisconsin River, a tributary to the Mississippi River. Future stockings will be from eggs obtained by the Wisconsin Department of Natural Resources from the Mississippi River basin (MDOC 2007).

Illinois River, Illinois

The Illinois River is a principal tributary of the upper Mississippi River in Illinois.

Lake sturgeon formerly occurred in the Illinois River in Illinois, but were rare by the early 1900s (Nyboer et al. 2006).

Missouri River Basin



Missouri River and tributary areas with former and current lake sturgeon spawning populations

Basin-wide Distribution and Abundance

Lake sturgeon were formerly abundant in the Missouri River basin, but populations declined drastically in the early 1900s due to overfishing and habitat degradation (Carlson and Pflieger 1981; Pflieger 1997). In 1895, 50,000 pounds of lake sturgeon were harvested commercially from the Missouri and Mississippi rivers in Missouri (MDOC 2007). Lake sturgeon rapidly went from being a species of economic importance in 1900 to classified as rare by 1908, and were nearly extirpated from the lower Missouri River by the early 1900s (Carlson and Pflieger 1981; Pflieger 1997).

Though there were infrequent catches of lake sturgeon by commercial fishers from the 1960s through the early 1980s, the lake sturgeon population in Missouri's big rivers was thought to be extremely low (Pflieger 1997). Natural reproduction was either non-existent in Missouri or survival of young was not sufficient to increase population numbers (MDOC 2007). Though some sturgeon have been found over the past few decades, lake sturgeon are now very rare in Missouri (Carlson and Pflieger 1981; MDOC 2007). Gavins Point Dam at river mile 811 in Yankton, South Dakota, is a complete barrier to upstream sturgeon migration (Wilcox, et al. 2004).

Reintroduction of lake sturgeon by the Missouri Department of Conservation began in the lower Missouri River in 1984 (Drauch and Rhodes 2007). Stocked lake sturgeon are now encountered by anglers and biologists up the Missouri River to the tailwaters of Gavins Point Dam (MDOC 2007), but there is no known reproduction and the population is far from self-sustaining (MDOC 2007).

<u>Missouri River, South Dakota/Nebraska/Missouri/Kansas</u>

The Missouri River is the northwestern-most drainage to the Mississippi River. It flows from the Rocky Mountains through Montana, Wyoming, North Dakota, South Dakota, Nebraska, northeastern Colorado, northern Kansas, southwestern Iowa and Missouri, joining the Mississippi River in St. Louis, Missouri.

Lake sturgeon were previously found throughout the Missouri River drainage (Johnsgard 2005). Although lake sturgeon were reported to have historically been uncommon with a sporadic or rare distribution in the Missouri River along Nebraska's eastern border, more than 7,100 lbs of lake sturgeon were harvested from the Missouri River in 1894, principally around Niobrara, Dakota, Blair, Omaha, Plattsmouth and Nebraska City (Steffensen et al. 2014). Between 1962 and 2002, fisheries monitoring by the Nebraska Game and Parks Commission only resulted in the capture of 3 sub-adult lake sturgeon from the Missouri River, near Brownville in 1971 (Steffensen et al. 2014). A single specimen was caught and released from the Missouri River in Kansas in 1988 (Haslouer et al. 2005). By the 1990s lake sturgeon were thought to be extirpated from the Nebraskan part of the Missouri watershed (Hesse et al. 1993, p. 333; Steffensen et al. 2014).

The Missouri Department of Conservation began stocking fingerling lake sturgeon from Lake Winnebago into the Missouri River in 1992 (Drauch and Rhodes 2007; MDOC 2007), with release sites in Cooley Lake, Waverly, Boonville, Mokane, Hermann, Washington and New Haven, Missouri (MDOC 2007). MDC has stocked more than 149,000 hatchery-reared lake sturgeon in the Missouri River at 13 different sites in the lower 546 km of the river (Steffensen et al. 2014). Accordingly, 40 juvenile and sub-adult lake sturgeon, likely of hatchery origin, have been collected by the Nebraska Game and Parks Commission since 2003, from the Missouri River along Nebraska's border: from below Gavin's Point Dam; at the mouth of the Big Souix River; and downstream of the confluence with the Platte River (Steffensen et al. 2014). Lake sturgeon is the rarest sturgeon species sampled from the Missouri River along Nebraska's border (Steffensen et al. 2014).

Platte River, Nebraska

The Platte River is a tributary of the Missouri River in Nebraska. Lake sturgeon were previously found in the Platte River, (with a record at the mouth of the Platte in 1942; Steffensen et al. 2014), but they are now extirpated (Johnsgard 2005).

Kansas River, Kansas

The Kansas River flows through northeastern Kansas and is the southwestern-most part of the Missouri River drainage.

Before 1970, lake sturgeon populations in Kansas were reduced by up to 80% (KDWPT 2015b). The current lake sturgeon population is unknown in the Kansas River, but there has been just one recent specimen reported (in 1997) from its lower section (Haslouer et al. 2005). Lake sturgeon collected in Kansas most likely are from a propagation and stocking effort by the state of Missouri (KDWPT 2015b). A ban on commercial harvest of lake sturgeon has existed since 1970.

Osage River, Missouri

The Osage River is a tributary of the Missouri River in central Missouri.

Pflieger (1997) reported that before Bagnell Dam impounded the Osage River in 1931, lake sturgeon were often caught in the lower portion of that stream.

Ohio River Basin

Basin-wide Distribution and Abundance

Lake sturgeon were formerly abundant throughout the Ohio River and many of its major tributaries, but populations were greatly reduced basin-wide by 1950 and have suffered massive declines since the 1950s (McCormick 1892; Trautman 1981; Pearson and Krumholz 1984; Drauch et al. 2008). Lake sturgeon are now nearly extirpated from the Ohio River and all of its major tributaries in Ohio, Kentucky, Indiana, Pennsylvania, West Virginia and Tennessee (Lachner 1956; Pearson and Krumholz 1984; Drauch et al. 2008). Former lake sturgeon populations have been extirpated from the Allegheny, Cumberland, Ohio, Scioto, Tennessee and Wabash rivers.

Only one small naturally reproducing population of lake sturgeon remains in the entire Ohio River basin, in the East Fork of the White River tributary of the Wabash River in southern Indiana. Although lake sturgeon once inhabited most of the largest rivers of the Ohio River drainage, only a remnant population with very limited range remains in portions of the East Fork White River, in primarily Lawrence and Martin counties.

Stocking of hatchery lake sturgeon has begun in the Cumberland and Tennessee Rivers in Kentucky and Tennessee (TWRA 2012; KDFWR 2014); unfortunately upper Mississippi River lake sturgeon have been stocked in the Cumberland River INDNR 2012).

<u>Ohio River</u>

The Ohio River is the largest tributary of the Mississippi River and flows from western Pennsylvania through Ohio, West Virginia, Kentucky and Indiana before its confluence with the Wabash River in Indiana and Illinois. The Ohio River basin includes tributaries in Tennessee.

Ohio River and tributary areas with former and current lake sturgeon spawning populations

Historical records indicate that lake sturgeon were once widely distributed and abundant throughout the Ohio River system (Jordan 1878; Lachner 1956; Trautman 1981; Pearson and Krumholz 1984; Burr and Warren 1986; Drauch et al. 2008; ODNR 2015b). Historical records document the presence of lake sturgeon in the Ohio River from western Pennsylvania to its confluence with the Wabash River in Indiana (Jordan 1878; Lachner 1956; Trautman 1981). Lake sturgeon were “abundant” and “very common” in Ohio in the 1800s (McCormick 1892; Trautman 1981; Pearson and Krumholz 1984), and supported a commercial fishery before 1900 (Pearson and Krumholz 1984). Lake sturgeon were likely found historically throughout most of Kentucky’s larger rivers, nearly all of which are tributaries of the Ohio River (Clay 1975). Burr and Warren (1986) reported 8 pre-1950 records of lake sturgeon in Kentucky rivers. Lake sturgeon were once a common inhabitant of all the largest rivers in Indiana, including the Ohio River (INDNR 2006). Tributary streams were essential spawning areas for lake sturgeon in the Ohio River basin (Pearson and Krumholz 1984), and lake sturgeon would make spawning runs far up tributaries (ODNR 2015).

The placement of navigation dams in the Ohio River essentially rendered most of the basin's habitat unsuitable for lake sturgeon (Trautman 1981). Declines of lake sturgeon in the Ohio River system were noted as early as the turn of the nineteenth century (Trautman 1981). Declines within the Ohio River mainstem have been attributed to the river's impoundment, as well as pollution, habitat destruction, and commercial overharvest (Lachner 1956). Lake sturgeon have not been seen in West Virginia since at least the 1940s (Cincotta 2004) and are likely extirpated from West Virginia (WVDNR 2015b). There were a few isolated sightings of lake sturgeon in the Ohio River recorded as late as 1969-1971 (Pearson and Krumholz 1984; ODNR 2015b), but between 1970 and 1984 populations seemed to reach a considerable low and no lake sturgeon were reported (Pearson and Krumholz 1984). There were 4 lake sturgeon records from Kentucky from 1984-1986, from the lower Ohio River and the Ohio Brush-White Oak Creek, lower Ohio-Bay and Highland-Pigeon tributaries, but these were thought to be transient fish, not representing permanent lake sturgeon populations (Burr and Warren 1986). The lake sturgeon has reportedly been observed recently in the lower Ohio River in Illinois (Nyboer et al. 2006), but no details were given.

Allegheny River, New York/Pennsylvania

The Allegheny River is a principal tributary of the Ohio River in New York and Pennsylvania.

Lake sturgeon were once abundant in the Allegheny River and occurred all the way upstream to Warren, Pennsylvania, but were nearly extirpated by the early 1900s (Criswell 2014).

Scioto River, Ohio

The Scioto River is a tributary of the Ohio River in Ohio.

Lake sturgeon historically migrated up the Scioto River as far upstream as Columbus, Ohio (Carlson 1995).

Wabash River, Ohio/Indiana/Illinois

The Wabash River is the largest tributary of the Ohio River, flowing through Ohio, Indiana and Illinois.

Lake sturgeon were formerly common in the Wabash River, but were rare by the early 1900s (INDNR 2006; Nyboer et al. 2006).

East Fork White River, Indiana

The East Fork of the White River is a tributary of the Wabash River in southern Indiana.

Lake sturgeon were formerly common in the White River (INDNR 2006). A small stretch of the East Fork of the White River now contains the only remaining lake sturgeon population in the entire Ohio River drainage (INDNR 2006; Simon 2006; Drauch et al. 2008). Adult and juvenile lake sturgeon were found in the East Fork White River in the late 1990s and early 2000s, and it was presumed that spawning was most likely occurring (Galarowicz 2003).

In 2005 lake sturgeon spawning (several fish) was documented in the East Fork White River for the first time and larval lake sturgeon were collected from the river just below the spawning area (INDNR 2006). The only known spawning area in East Fork White River is just downstream from Williams Dam, a hydropower structure built in 1913 that is a barrier to further upstream movement of lake sturgeon (INDNR 2013). Williams Dam was mothballed in 1948 but is now being revived for electrical generation (INDNR 2013). Lake sturgeon have been documented spawning below Williams Dam every year since 2005; nearly 100 individual lake sturgeon have been identified (INDNR 2013).

A study through Purdue University was completed in 2006 to determine if the genetic structure of the East Fork White River lake sturgeon population is unique. Results showed these fish to be genetically distinct from other lake sturgeon populations, sufficiently different enough from Great Lake populations to warrant conservation as a distinct population, and that they do not appear to be contaminated by non-native stocks (Drauch et al. 2008). Drauch et al. (2008) concluded that any type of augmentation to the East Fork White River population or reintroductions in other parts of the Ohio River drainage should only be attempted using East Fork White River lake sturgeon.

Cumberland River, Kentucky/Tennessee

The Cumberland River is a tributary of the Ohio River that flows through Kentucky and Tennessee.

Lake sturgeon were once abundant in the Cumberland River, but have since declined (Harned and Hackney 1981; Burr and Warren 1986). Burr and Warren (1986) reported only one post-1950 record of lake sturgeon in the Cumberland River in Kentucky. The last known occurrences of native lake sturgeon in the Cumberland River were recorded in 1954 (KDFWR 2014) and 1968 (Harned and Hackney 1981). Two large adult lake sturgeon (4.5 feet and 6.5 feet) of unknown origin were captured in 1977 and 1978 below Codell Hull Dam in the Cumberland River (Harned and Hackney 1981). Other accounts of lake sturgeon in the Cumberland River are fairly limited, and the species is listed as endangered on the Tennessee Wildlife Resources Agency's list of endangered and threatened fishes (Harned and Hackney 1981).

The Tennessee Wildlife Resources Agency and Tennessee Aquarium began releasing hatchery lake sturgeon into the Cumberland River in 2000 (TWRA 2012). In 2007, the Kentucky Department of Fish and Wildlife Resources began stocking lake sturgeon into the upper Cumberland River drainage, where the species once occurred (KDFWR 2014). KDFWR receives fertilized lake sturgeon eggs annually from the Wisconsin Department of Natural Resources taken from out of basin, from upper Mississippi River basin stock (INDNR 2012; KDFWR 2014). The stocking area includes the upper Cumberland River drainage from Wolf Creek Dam (Lake Cumberland) upstream to Cumberland Falls; stocked tributaries include the Big South Fork, Rockcastle River, and the mouth of the Laurel River (KDFWR 2014). Monitoring of radio-tagged sturgeon revealed that stocked fish often remained at or returned to stocking sites, displaying high site fidelity towards those areas, although 63% found their way into tributaries and 50% moved downriver into Lake Cumberland during various times (Herrala 2015).

Tennessee River, Tennessee/Ohio/Alabama/Mississippi

The Tennessee River is a tributary of the Ohio River flowing through the Tennessee Valley in Tennessee, Ohio, Alabama and Mississippi.

Lake sturgeon were formerly abundant in the Tennessee River, but have since declined (Harned and Hackney 1981; Burr and Warren 1986). Lake sturgeon were documented historically at two locations in the Tennessee River in Alabama (ADCNR 2015).

The Tennessee Wildlife Resources Agency and Tennessee Aquarium began stocking hatchery lake sturgeon into the upper Tennessee River system in 2000 (TWRA 2012), using sturgeon from the Wolf (Great Lakes), Yellow, and Wisconsin Rivers in Wisconsin (Saidak 2015). Monitoring of reintroduced lake sturgeon with acoustic transmitters from 2013-2015 documented sturgeon use and dispersal in the upper Tennessee (river miles 427-632), Clinch (rm 0-5), Hiwassee (rm 5-501.9), Holston (rm 0-52.2), and French Broad rivers (rm 0-32.3); as well as aggregations in Fort Loudoun Reservoir and smaller numbers in Watts Bar and Chickamauga Reservoirs (Saidak 2015).

French Broad River, Tennessee

The French Broad River is tributary of the Tennessee River in Tennessee.

Releases of hatchery lake sturgeon into the French Broad River began in 2013 (Benson 2013).

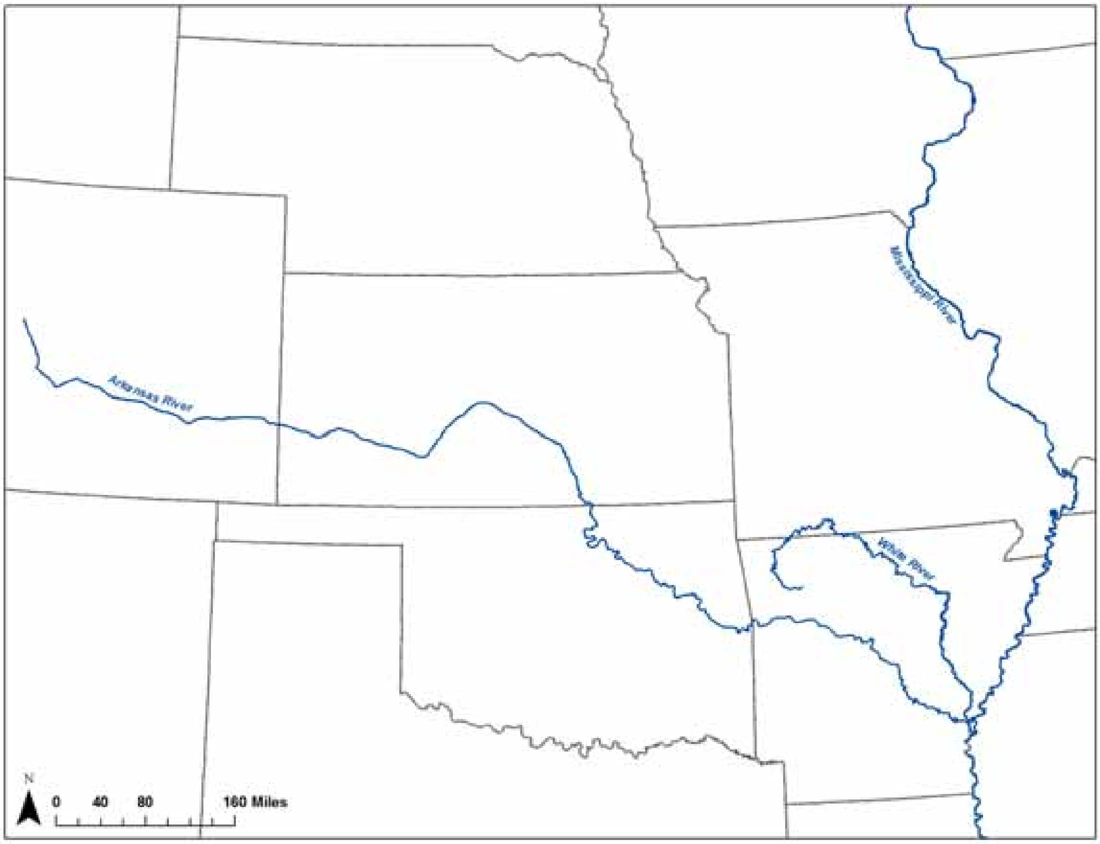
Arkansas-White River Basin

The Arkansas-White River basin includes the Arkansas and White Rivers, and drains southeastern Colorado, northern Oklahoma, southern Kansas and northwestern Arkansas, flowing into the lower Mississippi River.

Very little is known about lake sturgeon within Arkansas (Buchanan et al. 1993).

White River, Arkansas

Prior to 1988 only three records for lake sturgeon existed in Arkansas (Robison and Buchanan 1988; Buchanan et al. 1993). There have been two modern accounts of lake sturgeon in the White River: a female taken in May 1989 by a commercial fisherman in Desha County, Arkansas; and a live lake sturgeon discovered in April 1992 at a fish market in Brasfield, Arkansas, which was released alive back in to the White River after identification (Buchanan et al. 1993). Subsequently, Buchanan et al. (1993) recommended that lake sturgeon be categorized as endangered due to its rarity within the state. Despite these sightings, the species is assumed to be essentially extirpated from Arkansas (NatureServe 2003) and has a state designation in Arkansas as a species of special concern (AGFC 2013).



Arkansas and White Rivers

Lower Mississippi River Basin

Basin-wide Distribution and Abundance

The lower Mississippi River basin, downstream of the confluence of the Mississippi River and the Ohio River, at Cairo, Illinois, includes the lower Mississippi River and tributaries in Louisiana, Mississippi, Arkansas, Missouri and Tennessee. There is little historical information on lake sturgeon in the lower Mississippi River basin, and no recent records. Stocking of hatchery lake sturgeon has occurred in Louisiana.

<u>Lower Mississippi River</u>

There are two historical records of lake sturgeon from the lower Mississippi River (Crump and Robison 2000), and it is known that lake sturgeon formerly occurred in the lower Mississippi River in Tennessee (TWRA 2012).

Beginning in 1984, the Missouri Department of Conservation began stocking fingerling lake sturgeon from Lake Winnebago into the lower Mississippi River in Louisiana (Drauch and Rhodes 2007).

Lower Mississippi River basin areas with historical and recent lake sturgeon locations

Ouachita River Basin, Arkansas

Caddo River, Arkansas

A very large (9 feet, 10 inches) lake sturgeon was taken in 1945 from the Caddo River, a tributary of the Ouachita River, in Arkansas (Crump and Robison 2000). Lake DeGray Dam on the Caddo River was constructed downstream from this site from 1963-1972.

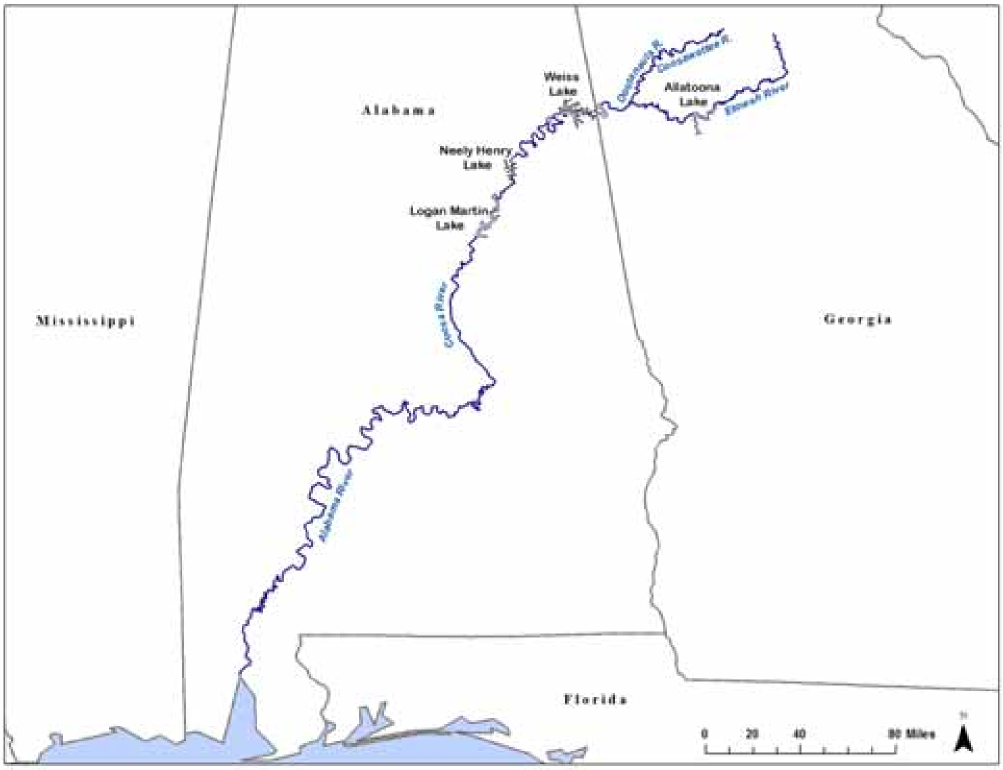
Little Missouri River, Arkansas

Another large (6 feet, 6 inches) lake sturgeon was taken in 1956 from the Little Missouri River, a tributary of the Ouachita River (Crump and Robison 2000).

Alabama-Georgia

Basin-wide Distribution and Abundance

Former lake sturgeon populations in the southern United States were decimated during the late 1800s and early 1900s by overfishing, pollution and dam construction (Rochard et al. 1990; Birstein 1993; Peterson et al. 2007). Lake sturgeon were extirpated from the Coosa River and its tributaries by the 1960s or 1970s (GDNR 2013). Small numbers of stocked sturgeon of Wisconsin origin are surviving in the Coosa River and its Etowah, Coosawattee and Oostanaula tributaries, but there are no fish of reproductive age.



Alabama and Georgia rivers with former and current lake sturgeon spawning populations

<u>Coosa River, Alabama/Georgia</u>

The Coosa River flows through Georgia and Alabama, and is a tributary of the Alabama River, which flows into the Gulf of Mexico near Mobile, Alabama. The river is about 280 miles long and is one of Alabama's most developed rivers, with most of the river now impounded by 7 hydroelectric dams.

A lake sturgeon population historically occurred in the upper Coosa River system (Freeman et al. 2005), and sturgeon were known to spawn formerly at two locations in the Coosa River (ADCNR 2015).

In the mid-1900s, a remnant isolated, but naturally reproducing population of lake sturgeon was identified in the Coosa River (Smith-Vaniz 1968; Dahlberg and Scott 1971; Bezold and Peterson 2008; Peterson and Bezold 2008). Lake sturgeon were caught in the Coosa River by anglers from the 1930s to the 1970s (Freeman et al. 2005). Anglers reported good harvests of lake sturgeon into the early 1960s but the population was extirpated by the 1970s, likely due to overharvest and degraded water quality (Peterson and Bezold 2008; GDNR 2013). Despite improvement in water quality following passage of the Clean Water Act, an absence of recent sightings led to the presumption by the Georgia Department of Natural Resources (GDNR) that lake sturgeon were extirpated from the Alabama and Coosa River system (Freeman et al. 2005; ANHP 2012; GDNR 2013). GDNR biologists reviewed 40 years of general fish sampling data from the area, consulted with citizens and staff of other agencies, and sampled specifically for sturgeon using a variety of methods, and found no substantiated evidence that lake sturgeon remained in the Coosa system after the middle 1960s (GDNR 2013).

In 2002 the GDNR initiated a 20-year lake sturgeon reintroduction program (Bezold and Peterson 2008; Peterson and Bezold 2008), intended to reestablish a self-sustaining population in the Coosa River basin. The reintroduction program used sturgeon eggs from the Fox River (Lake Winnebago system) in Wisconsin (Beisser 2007; Bezold and Peterson 2008). Since 2002, the GDNR has released more than 140,000 sturgeon fingerlings in the Coosa River basin (GDNR 2015b). Lake sturgeon are also being stocked in the Etowah, Coosawattee and Oostanaula tributaries because these were the last reported locations to contain lake sturgeon (GDNR 2013). The reintroduction effort has established a small population of juvenile lake sturgeon in the Coosa River, but only about 2.5% of initially stocked fish survived (Peterson and Bezold 2008). Using mark-recapture surveys, Bezold and Peterson (2008) estimated the abundance of stocked juvenile lake sturgeon in the Coosa River in 2006 to be 789 fish. Recaptured sturgeon from 2002-2004 releases have had higher than expected survival (GDNR 2013). Stocked lake sturgeon have been captured recently in Lake Weiss (on the Coosa River in Alabama) and in the upper Coosa River in Alabama (ADCNR 2015). Study results indicated that stocked lake sturgeon are utilizing the Coosa River from Rome, Georgia, downstream into and throughout Lake Weiss and Neely Henry and Logan Martin reservoirs in Alabama (GDNR 2013).

Etowah River, Georgia

The Etowah River is an upper tributary of the Coosa River in Georgia.

Historically, lake sturgeon occurred in the Etowah River tributary (GDNR 2014). Lake sturgeon were reportedly caught by anglers in the Etowah River from the 1930s to the 1970s (Freeman et al. 2005).

Lake sturgeon are being stocked by the GDNR into the Etowah River at numerous sites up-and downstream of Lake Allatoona, and stocked lake sturgeon are now utilizing the lower Etowah River (GDNR 2013, 2014).

Oostanaula River, Georgia

The Oostanaula River is an upper tributary of the Coosa River in Georgia.

Historically, lake sturgeon occurred in the Oostanaula River (GDNR 2014). There was a single record of a lake sturgeon from 1980 in a periodically flooded pond adjacent to the Oostanaula River (Freeman et al. 2005).

Lake sturgeon are being stocked by the GDNR into the Oostanaula River, and stocked fish are now utilizing the lower Oostanaula River (GDNR 2013, 2014).

Coosawattee River, Georgia

Lake sturgeon are being stocked by the GDNR into the Coosawattee River, one of the last reported locations to contain lake sturgeon (GDNR 2013).

Canada

The distribution of lake sturgeon in Canada includes rivers of Hudson Bay, the Great Lakes, and inland lakes and rivers of Alberta, Saskatchewan, Manitoba, Ontario and Quebec (COSEWIC 2006). In the northern part of their Canadian distribution, lake sturgeon range from the Churchill River on the west side of Hudson Bay in the northwest, to the La Grande River on the east side of Hudson Bay in the northeast (Harkness and Dymond 1961; Scott and Crossman 1998). In the southern part of its Canadian distribution, the species ranges from the South Saskatchewan River in western Alberta (McLeod et al. 1999) to the St. Lawrence River at Saint-Roch-des-Aulnaies, about 125 km downstream from Québec City, in the east (Scott and Crossman 1998). Lake sturgeon are also present in the lower sections of the larger rivers draining into the St. Lawrence River west of salt water influence (e.g. the L'Assomption, Richelieu, Saint-François, Saint-Maurice, Batiscan, and Chaudière rivers) (COSEWIC 2006). Lake sturgeon co-occur with Atlantic sturgeon in the upper part of the St. Lawrence River, from Lake Saint-Pierre to the limits of fresh water (COSEWIC 2006).

As discussed above, Canada (COSEWIC 2006) recognizes 8 distinct regional populations of lake sturgeon in Canadian waters, based on genetic distinctions and biogeographic zones: Western Hudson Bay; Saskatchewan River; Nelson River; Red/Assiniboine Rivers-Lake Winnipeg; Winnipeg River-English River; Lake of the Woods-Rainy River; Southern Hudson Bay-James Bay; and Great Lakes-Upper St. Lawrence.

Western Hudson Bay Population

Historic fishery information indicates a lake sturgeon decline in Western Hudson Bay of over 90% between the 1920s and 1940s, with no evidence of subsequent substantial increase. Life history traits of harvested lake sturgeon in the 2000s are consistent with a population that has been subject to severe overexploitation and has not recovered, and records of mature individuals were almost non-existent by the early 2000s. The only available population estimate, for part of one watershed (Churchill River) in Western Hudson Bay, estimated between 1,300 and 2,300 adults, but this estimate is likely biased upward. Historically, overfishing was probably the primary threat for Western Hudson Bay sturgeon populations; more recently, dams are probably the most important threat. (See: Skaptason 1926; SERM 1996; MacLean and Nelson 2005; COSEWIC 2006).

The Committee on the Status of Endangered Wildlife in Canada designated Western Hudson Bay populations of lake sturgeon as “endangered” in 2006 (COSEWIC 2006).

Saskatchewan River Population

All estimates of lake sturgeon population status in the Saskatchewan River suggest major reductions from the 1920s to the 1960s and 1970s, but these declines are difficult to quantify. Since the 1970s, there has been a further decline of as much as 80% in the Saskatchewan River population. Seventy-six of 111 historic lake sturgeon sites (68%) in Saskatchewan and Alberta have been lost. There was an 80% decline reported in the Cumberland House area from 1960-2001; and a 50% decline from 1998 to 2003 was reported in the lower Saskatchewan River from Cumberland House to The Pas in Manitoba. Current density estimates from a variety of sources are consistently very low, and estimates of the numbers of breeding females in various river branches do not exceed a few dozen spawners annually. The information on age and size composition of components of this population are also consistently indicative of a population that has been affected by heavy exploitation and habitat disruptions for a long period, although recruitment to the populations is still occurring. (See: Skaptason 1926; Moodie 1965; Houston 1987; Wallace 1991; Nelson and Paetz 1992; Findlay 1995; Findlay et al. 1995; Seylor 1997a, 1997b; Wallace and Leroux 1999; Bretecher and MacDonell 2001; ASRD 2002; North/South Consultants 2002; Smith 2003; COSEWIC 2006).

The Committee on the Status of Endangered Wildlife in Canada designated Saskatchewan River populations of lake sturgeon as “endangered” in 2006 (COSEWIC 2006).

Nelson River Population

Historic commercial fishery data indicated large but unquantified declines in abundance of the Nelson River lake sturgeon population since the first quarter of the 1900s. For the period since population estimates have become available for components of this population, estimates of the largest component declined 80-90% from the early 1960s to the late 1990s, and have declined further thereafter. A lake sturgeon fishery at Sipiwesk Lake exhibited an 80-90% decline in landings from 1987-2000; groups of only 5-6 spawning fish were observed in the Landing River in 1990 compared to hundreds observed several decades ago. Historically, overfishing probably was the primary threat for these populations; more recently, dams are probably the most important threat. Dams in the Nelson River system have fragmented the population into largely isolated components, some of which appear to have been extirpated. All sturgeon populations that have been studied show few spawners annually, few eggs and larvae, a low proportion of mature sturgeon in samples, and a small maximum size of the mature sturgeon that are found. (See: Sunde 1961; Sopuck 1987; Choudhury and Dick 1993; Horne and Baker 1993; MDNR 1994; MacDonnell 1995; MacDonnell 1997; Macdonald 1998; Macdonnell 1998; Barth and MacDonnell 1999; Barth 2005; Barth and Ambrose 2006; COSEWIC 2006).

The Committee on the Status of Endangered Wildlife in Canada designated Nelson River populations of lake sturgeon as “endangered” in 2006 (COSEWIC 2006).

Red-Assiniboine Rivers/Lake Winnipeg Population

Very large populations of lake sturgeon must have once existed in Lake Winnipeg, but these populations were depleted by commercial exploitation in the first decades of the 1900s; historic sizes of population components in rivers in the range of Red-Assiniboine Rivers/Lake Winnipeg are poorly known, but all are known to be depleted. There was no firm evidence of naturally reproducing populations in the major watersheds of the Assiniboine or Red Rivers in the early 2000s, although there had been minimal angling catches each year. A number of smaller rivers draining into Lake Winnipeg continued to support lake sturgeon in the early 2000s, but the little evidence available suggested that numbers of spawning females were unlikely to exceed 100 annually in any component. Stocking had been undertaken in the major rivers of Red-Assiniboine Rivers/Lake Winnipeg since 1996, but survival rates appeared to be low, and it would be at least one or two more decades before lake sturgeon stocked in these rivers could establish reproducing populations if they were to survive. The virtual disappearance of lake sturgeon from the Red-Assiniboine River and Lake Winnipeg was primarily the result of overfishing, although dams probably also affect remnant populations. (See: Lysack 1986; Dick 2004; Graveline and MacDonnell 2005; COSEWIC 2006)

The Committee on the Status of Endangered Wildlife in Canada designated the Red-Assiniboine Rivers/Lake Winnipeg population of lake sturgeon as “endangered” in 2006 (COSEWIC 2006).

Winnipeg River/English River Population

Winnipeg River/English River populations of lake sturgeon were large enough to produce commercial catches of over 35,000 kg in the 1930s, but these catches were unsustainable and the populations were unable to support catches of less than a third that size by the 1950s. Although commercial fisheries were closed since the 1970s, lake sturgeon were uncommon to rare by the early 2000s at sites that historically were major spawning beds, and lake sturgeon rarely were taken in angling and subsistence catches. A single mark-recapture estimate was available for a major portion of the population in the Winnipeg River/English River in the late 1990s, and it suggested it was unlikely that the mature population exceeded 660 fish, of which less than half were female, and only a portion of these would spawn each year. Limited recent data show that lake sturgeon populations are declining in the Winnipeg River above Seven Sisters Dam, and essentially have disappeared below the dam. Historically, overexploitation probably was the primary threat for these populations; now dams and poaching probably are the most important threats. (See: Harris et al. 2000; COSEWIC 2006)

The Committee on the Status of Endangered Wildlife in Canada designated Winnipeg River/English River populations of lake sturgeon as “endangered” in 2006 (COSEWIC 2006).

Lake of the Woods/Rainy River Population

Lake sturgeon in the Lake of the Woods/Rainy River population were reduced by commercial fishing in the 1800s, but there has been substantial rebuilding of many stock components, particularly in recent decades. A total population estimate is not available, but estimates of the Rainy River/Lake component of the Lake of the Woods component exceeds 50,000 lake sturgeon greater than 1 m, and exploitation rates appear sustainable. Some population components still have an age composition skewed towards younger fish, but in most components where estimates are available, the proportion of mature fish is either stable or increasing. Although dams have not impeded access to important stretches of suitable habitat, dams do restrict immigration from the adjacent Winnipeg River. (See: Macins 1972; Mosindy and Rusak 1991; McLeod 1999; Stewig 2005; COSEWIC 2006)

The Committee on the Status of Endangered Wildlife in Canada designated Lake of the Woods/Rainy River populations of lake sturgeon as “special concern” in 2006 (COSEWIC 2006).

Southern Hudson Bay/James Bay Population

Although there are limited population data available for lake sturgeon populations in Southern Hudson Bay/James Bay (in Manitoba, Ontario and Quebec), there have been declines in sturgeon habitat and possibly abundance for some population components related to fishing and the multitude of dams. Lake sturgeon population components in a number of watersheds through northeastern Manitoba, northern Ontario, and northwestern Quebec appear healthy, but generally are poorly quantified, and in a few watersheds, different reports of population status are inconsistent. Some components in Quebec and Ontario have been fragmented by hydroelectric dams; whereas hydroelectric developments have created the potential for connection between other watersheds supporting lake sturgeon, increased hydroelectric development in some areas are causes for concern for Southern Hudson Bay/James Bay lake sturgeon. Many northern drainages have not been subjected to commercial fisheries, and where commercial fisheries have occurred, all but three small fisheries have been closed due to unsustainable harvesting in the past. Increased fishing access to relatively unimpacted sturgeon populations is a concern. (See: Nowak and Jessop 1987; Ecologistics 1988; Fortin et al. 1992; Sheenan and McKinley 1992; INAC 1993; Seyler et al. 1996, 1997a,b,c; Ferguson and Duckworth 1997; Hydro-Québec 2001; Bernatchez and Saint-Laurent 2004; Hydro-Québec 2004a,b; MRNF 2005; COSEWIC 2006)

The Committee on the Status of Endangered Wildlife in Canada designated Southern Hudson Bay/James Bay populations of lake sturgeon as "special concern" in 2006 (COSEWIC 2006).

Great Lakes/Upper St. Lawrence Population

Shortly after Canadian waters of the Great Lakes were opened to commercial sturgeon fishing in 1879, populations of lake sturgeon throughout the Great Lakes and in the surrounding water bodies in Canada and the U.S. declined to less than 1% of their former numbers. A variety of trends are seen in lake sturgeon population components in the Canadian portion of the Great Lakes. A very large commercial fishery for lake sturgeon existed in the Great Lakes between the mid-1800s and early 1900s, during which time sturgeon populations were reduced to a small fraction of their original size. Throughout the Great Lakes, lake sturgeon abundances are certainly much lower than they were historically, but self-sustaining population units are present in all the Great Lakes and many tributaries. As of the early 2000s, lake sturgeon populations were extant at 63 sites in the Great Lakes and St. Lawrence basin; however, successful spawning was documented from only 20 sites and was unknown for the rest. Spawning run size estimates were available for only 17 of these sites, and populations at only 4 of these sites were considered to have a spawning run greater than 500 adults. As many as 20 spawning populations in the Great Lakes may have been lost, but other populations were showing signs of modest recovery.

Most commercial fisheries in the Great Lakes have been closed or greatly reduced for many decades, and usually recreational catches are tightly restricted as well. Many spawning components remain in the Great Lakes and their tributaries, and some monitoring programs suggest that abundances are increasing. However, age composition of essentially all population components tend to lack older fish, numbers of spawners are often low each year, and many traditional spawning sites are not used. Lake sturgeon populations appear to be declining in parts of the Ottawa River, and disappearing from many of its tributaries due to dams. Despite recovery efforts there has been a recent decline in the population in the St. Lawrence River, probably due to overfishing. The direct and indirect effects of dams, chemical control of sea lamprey, contaminants and invasive species currently threaten Great Lakes/Upper St. Lawrence sturgeon populations. (See: Small 1883; Prince 1905; Dymond 1939; Toner 1943; Harkness and Dymond 1961; Christie 1973; Dumont et al. 1987; Fortin et al. 1992; La Haye et al. 1992; Fortin et al. 1993; Carlson 1995; Kelso and Cullis 1996; Mohr 1996-2000; Hay-Chmielewski and Whelan 1997; McMurtry et al. 1997; Nilo et al. 1997; Seyler 1997a,b; Johnson et al. 1998; OMNR and GQFP 1999; Dumont et al. 2000a,b; Holey et al. 2000; Faucher and Abbott 2001; Alliance Environnement et al. 2002; Environnement Illimité 2002; Fortin et al. 2002; Haxton 2002; Dumas et al. 2003; Paradis and Malo 2003; Fleury and Desrochers 2004; Garceau and Bilodeau 2004; Mingelbier et al. 2004, 2005a,b; Dumont et al. 2005; MRNF 2005; Quinlan 2005; Dumont et al. 2006; Friday 2006; Friday and Chase 2006; Haxton 2006; Trencia and Collin 2006; COSEWIC 2006)

The Committee on the Status of Endangered Wildlife in Canada designated Great Lakes/Upper St. Lawrence populations of lake sturgeon as “threatened” in 2006 (COSEWIC 2006).

Population Trends

Range-wide

Lake sturgeon populations are estimated to have declined by 90 percent across their range (Williamson 2003; NatureServe 2003). Lake sturgeon are extirpated from 5 of the 20 U.S. states where they historically occurred, are endangered or critically imperiled in 11 states, and imperiled or vulnerable in 4 more; nowhere is the species listed as “apparently secure” or “secure” (NatureServe 2003). Lake sturgeon are recognized by the American Fisheries Society as “threatened” in North America.

Lake sturgeon were listed by the IUCN as “Vulnerable” from 1986 to 1996. In 2004, the IUCN down-listed lake sturgeon to “Least Concern” with an increasing population trend. However, the Mississippi and Missouri basin subpopulations remain in the threatened categories, listed as Vulnerable (IUCN 2004).

Great Lakes

More than half (at least 38) of former lake sturgeon spawning populations in U.S. tributaries of the Great Lakes have been extirpated. Lake sturgeon abundance is now less than 1% of historical numbers throughout the Great Lakes (Hay-Chmielewski and Whelan 1997; MSU and MDNR 2015). Most surviving populations in the Great Lakes have small annual spawning runs of fewer than 200 fish (MSU and MDNR 2015).

Lake Superior

Lake sturgeon went from being extremely abundant historically in Lake Superior (estimates of 57,000 adult sturgeon over 50 pounds in 1840, and a biomass of 2.13 million pounds in 1885) to collapse of the population in the early 1900s (Hay-Chmielewski 1997; Auer 2003; Haxton et al. 2014). Current abundance in Lake Superior is a fraction of historic levels (Hayes and Caroffino 2012). Former spawning populations were extirpated from 7 of 9 (78%) tributaries (the Manitou, St. Louis, Ontonagon, Montreal, Big Iron, Pigeon and Tahquamenon rivers) on the U.S. side of Lake Superior (Auer 2003; Zollweg et al. 2003; Pratt 2008). Only 3 of 22 (14%) former spawning populations are extant in all Lake Superior tributaries in Canada and the U.S. (Harkness and Dymond 1961; Auer 2003; Zollweg et al. 2003; Quinlan 2007; Pratt 2008). On the

Canadian side of Lake Superior, former spawning populations have been extirpated from 7 tributaries (Pigeon, Wolf, Gravel, Prairie, White and Harmony rivers and Stokely Creek). Remaining populations in 8 Canadian tributaries (Kamanistiquia, Black Sturgeon, Nipigon, Pic, Michipicoten, Batchawana, Chippewa and Goulais rivers) are all small or have unknown population sizes (Kelso and Cullis 1996; Holey et al. 2000; Auer 2003; Chase 2006; COSEWIC 2006; Friday 2006; Friday and Chase 2006; Pratt 2008).

Successful natural reproduction and small, self-sustaining populations now occur only in the Sturgeon River and its tributary Otter River (estimated 200-400 spawners annually), and the Bad River and its tributary White River (estimated 250-350 spawners annually). Restoration stocking in the St. Louis and Ontonagon rivers has not yet established reproducing populations (Baker 2006; Pratt 2008; Hayes and Caroffino 2012; Cook 2015).

Lake Michigan

Lake sturgeon went from being incredibly abundant historically in Lake Michigan (estimates of up to 11 million sturgeon of all ages, 2.4 million adult sturgeon over 50 pounds in 1825, and a biomass of 18.68 million pounds in 1882) to collapse of the population in the early 1900s (Kinietz 1965; Tody 1974; Baldwin et al. 1979; Hay-Chmielewski and Whelan 1997; Slade and Auer 1997; Haxton et al. 2014). The most optimistic estimate of lake-wide abundance in the 1990s was 5,000-10,000 fish, well below 1% of the most conservative estimates of historic abundance (Hay-Chmielewski and Whelan 1997). Today, only about 3,000 adult lake sturgeon are believed to remain in Lake Michigan (Donofrio and Utrup 2013). Populations have been extirpated from 14 of 27 (52%) former spawning tributaries in Lake Michigan and are at dangerously low numbers in 10 additional tributaries (Holey et al. 2000; Welsh 2004; Schneeberger et al. 2005; Caroffino et al. 2007; Elliott 2008; USEPA 2009; Hayes and Caroffino 2012; Donofrio and Utrup 2013).

In western Lake Michigan, former spawning populations were extirpated from 12 of 20 (60%) tributaries (Sturgeon River, Whitefish River, Escanaba River, Ford River, Kewaunee River, East Twin River, West Twin River, Manitowoc River, Sheboygan River, Barr Creek, Milwaukee River and Root River), as well as from Brevoort Lake. Small remnant runs remain in 5 tributaries to western Lake Michigan (Millecoquins River, Manistique River, Indian River/Indian Lake, Cedar River and Oconto River), with no more than 25-50 annual spawners, well below minimum population viability. Only 3 significant populations remain in western Lake Michigan: in the Peshtigo River (~200 annual spawners); Menominee River (500-600 spawners in the lower river and landlocked populations upstream); and the large population in Lake Winnebago (~20,000 spawners in the entire system).

In eastern Lake Michigan, former spawning populations were extirpated from 2 of 7 (29%) tributaries (Galien River and Boardman River), as well as from Wolf Lake. Small remnant runs remain in 5 tributaries (St. Joseph, Kalamazoo River, Grand River, Muskegon River and Manistee River), with no more than 20-100 annual spawners, well below minimum population viability. There are no remaining large populations in eastern Lake Michigan.

Restoration stocking and streamside rearing facilities in the Milwaukee, Manitowoc, Manistee, Cedar and Whitefish rivers have not yet established reproducing populations (Holtgren et al. 2007; Baker et al. 2008).

Lake Huron

Lake sturgeon went from being extremely abundant historically in Lake Huron (estimates of 319,000 adult sturgeon over 50 pounds in 1840, and a biomass of 16.73 million pounds in 1879) to collapse of the population in the early 1900s (Hay-Chmielewski 1997; Haxton et al. 2014). Current abundance in Lake Huron and its tributaries remains far below historic levels (EPA 2009). Former spawning populations have been extirpated from 7 of 16 (44%) tributaries on the U.S. side (Au Sable, Cass, Saginaw, Shiawassee, Thunder Bay, Tittabawassee and Waiska rivers); most remaining populations (Black, Carp, Cheboygan, Indian, Pigeon, Rifle, Sturgeon and St. Marys rivers, and Burt and Mullet lakes) are well below minimum viable levels or near extirpation; and only 4 populations are considered stable (Zollweg et al. 2003; Pratt 2008; Hayes and Caroffino 2012). The single exception is in Black Lake, where the population was nearly extirpated but has been rebuilt as a result of intensive stocking efforts (Chalupnicki et al. 2011). Restoration stocking has also occurred in Burt Lake and Mullet Lake. In the Canadian portion of Lake Huron, lake sturgeon have been extirpated from 13 of 21 (62%) historical spawning tributaries (Holey et al. 2000); all 8 remaining populations are considered small (Hay-Chmielewski and Whelan 1997; Holey et al. 2000; Zollweg et al. 2003; COSEWIC 2006), with successful reproduction only known at 4 Canadian sites (COSEWIC 2006).

Lake Erie

Lake sturgeon went from being extremely abundant historically in Lake Erie and its tributaries (estimates of 535,000-580,000 adult sturgeon over 50 pounds in 1885, and a biomass of 56.03 million pounds in 1879) to rapid decline by 1897 and collapse by the early 1900s (Hartman 1973; MDNR 1973; Brousseau 1987; Carlson 1995; Hay-Chmielewski and Whelan 1997; Caswell 2002; Haxton et al. 2014). Current numbers in Lake Erie are well below historical levels (ODNR 2015a). At least 6 former spawning populations in U.S. tributaries of Lake Erie have been extirpated (Cuyahoga, Huron, Maumee, Raisin and Sandusky rivers, and Cattaraugus Creek) and the upper Niagara River has a very small remnant population; the only robust population is in the Huron-Erie corridor, with spawning in the Detroit River, Lake St. Clair and the St. Clair River (Thomas and Haas 2002; Pratt 2008; Hayes and Caroffino 2012). Even the relatively large Lake St. Clair population is significantly reduced from historical numbers.

Lake Ontario

Lake sturgeon went from being abundant historically in Lake Ontario and its tributaries (estimated biomass of 8.46 million pounds in 1879) to a population crash by 1900 (Christie 1973; Carlson 1995; COSEWIC 2006; Haxton et al. 2014). All of the former spawning populations in U.S. tributaries of Lake Ontario are extirpated or have only remnant runs, with small populations remaining only in the Black, Genesee, lower Niagara and Oswego rivers and in Oneida Lake. In Canadian tributaries of Lake Ontario, spawning has only been documented in the Trent River on an infrequent basis (USEPA 2009). Restoration stocking in the Black, Genesee, Indian, lower Niagara, Oswegatchie, Raquette, Salmon and St. Regis rivers, and in Black, Cayuga and Oneida lakes (Klindt and Adams 2005; Brooking et al. 2011; Chalupnicki 2011; Holbrook 2013a) has not yet established reproducing populations.

St. Lawrence River Basin

Historical lake sturgeon populations in the St. Lawrence River basin were dramatically reduced by commercial fishing from the mid-1800s to the early 1900s (COSEWIC 2006). Commercial catches in U.S. waters of the upper St. Lawrence River declined in the 1960s and the fishery was closed in 1976 (Zollweg et al. 2003); in Canadian waters the population was considered overexploited by 1987 (COSEWIC 2006). The St. Lawrence River population has continued to decline (COSEWIC 2006) and abundance has still not recovered from historical overfishing (NYSDEC 2014). Though lake sturgeon appear to remain relatively common in a few areas, most former lake sturgeon populations in U.S. waters of the St. Lawrence River and its tributaries (Grasse, Indian, Oswegatchie, Raquette and St. Regis rivers and Black Lake) are remnant or extirpated, with small spawning populations remaining in 3 of 4 (75%) Lake Champlain tributaries (Lamoille, Missisquoi and Winooski rivers). Although all 14 historically known Canadian population components in the St. Lawrence River and tributaries are extant, 12 are considered small and only 2 are large (Holey et al. 2000). Spawning is known to occur at 6 Canadian sites, is probably not occurring at 2 sites, and is unknown at 6 sites (Holey et al. 2000). Lake sturgeon stocking in the St. Lawrence River and tributaries (the Oswegatchie, Grasse, Raquette and St. Regis rivers and Black Lake) has not been hugely successful and spawning of stocked fish has only been documented in the Oswegatchie River (Heuvel and Edwards 1996; Elliott et al. 2008; USEPA 2009; Chalupnicki et al. 2011).

Northwestern Minnesota

In Northwestern Minnesota, formerly abundant lake sturgeon populations in the Red River and many of its tributaries have been largely extirpated. By the early 2000s, there was no evidence of naturally reproducing populations in the major watersheds of the Red River in Canada, and lake sturgeon were extremely rare in the Red River from Lake Winnipeg to the American border (COSEWIC 2006). Restoration stocking of lake sturgeon is occurring in the Red River in Minnesota, but reproducing populations have not yet been established. There are still relatively large numbers of lake sturgeon in the Lake of the Woods-Rainy River system and unknown numbers in Rainy Lake.

Mississippi River Basin

Naturally reproducing lake sturgeon have been essentially extirpated from most of the Mississippi River basin, with the exception of small populations that remain in tributaries of the upper Mississippi River (Chippewa, Flambeau, Kettle, Manitowish, Namekagon, Rock, St. Croix, Wisconsin and Yellow rivers); and the East Fork of the White River tributary in the Ohio River basin.

Upper Mississippi River

Lake sturgeon went from being extremely plentiful historically in the upper Mississippi River basin to rare. Small populations remain in the Chippewa, Flambeau, Kettle, Manitowish, Namekagon, Rock, St. Croix, Wisconsin and Yellow river tributaries. Former populations were extirpated from the Baraboo, Illinois, Minnesota and Snake river tributaries. Restoration stocking from in-basin populations has begun in the upper Mississippi River and the Flambeau, Fox, Manitowish, Namekagon, Salt, Wisconsin and Yellow river tributaries, but reproducing populations have not yet been established.

Missouri River

Formerly abundant lake sturgeon populations in the Missouri River basin declined drastically in the early 1900s (Carlson and Pflieger 1981; Pflieger 1997; MDOC 2007). Lake sturgeon rapidly went from being a species of economic importance in 1900 to classified as rare by 1908, and were nearly extirpated from the lower Missouri River by the early 1900s (Carlson and Pflieger 1981; Pflieger 1997). Lake sturgeon are now very rare in the Missouri River basin (Carlson and Pflieger 1981; Pflieger, 1997; MDOC 2007). Restoration stocking in the lower Missouri River has yet to result in reproduction and the population is far from self-sustaining (Drauch and Rhodes 2007; MDOC 2007).

Ohio River

Lake sturgeon were formerly abundant throughout the Ohio River and many of its major tributaries, but populations were greatly reduced basin-wide by 1950 and have suffered massive declines since the 1950s (McCormick 1892; Trautman 1981; Pearson and Krumholz 1984; Drauch et al. 2008). Lake sturgeon are now nearly extirpated from the Ohio River and all of its major tributaries in Ohio, Kentucky, Indiana, Pennsylvania, West Virginia and Tennessee (Lachner 1956; Pearson and Krumholz 1984; Drauch et al. 2008). Former lake sturgeon populations have been extirpated from the Allegheny, Cumberland, Ohio, Scioto, Tennessee and Wabash rivers. Only one small naturally reproducing population of lake sturgeon remains in the entire Ohio River basin, in the East Fork of the White River tributary of the Wabash River in southern Indiana. Restoration stocking in the Cumberland and Tennessee Rivers in Kentucky and Tennessee has not yet established reproducing populations (TWRA 2012; KDFWR 2014).

Arkansas-White River

Lake sturgeon are assumed to be essentially extirpated from the Arkansas River, though there were sightings in 1989 and 1992 of individual sturgeon in the White River (Robison and Buchanan 1988; Buchanan et al. 1993).

Lower Mississippi River

There is not much historical information on lake sturgeon in the lower Mississippi River basin, but the species was known to occur in the lower Mississippi River in Tennessee (Crump and Robison 2000; TWRA 2012). There are no recent records in the lower Mississippi River. Stocking of hatchery sturgeon from out of the basin (Lake Winnebago) has occurred in Louisiana (Drauch and Rhodes 2007).

Alabama/Georgia

Former lake sturgeon populations in the southern United States were decimated during the late 1800s and early 1900s (Rochard et al. 1990; Birstein 1993; Peterson et al. 2007). Lake sturgeon were extirpated from the Coosa River and its tributaries by the 1960s or 1970s (GDNR 2013). Small numbers of stocked sturgeon of Wisconsin origin are surviving in the Coosa River and its tributaries the Etowah, Coosawattee and Oostanaula rivers, but there are no fish of reproductive age.

Canada

As discussed above, Canada considers 5 lake sturgeon populations (Western Hudson Bay, Saskatchewan River, Nelson River, Red-Assiniboine Rivers/Lake Winnipeg, and Winnipeg River/English River) to be endangered; 1 population (Great Lakes/Upper St. Lawrence) to be threatened; and 2 populations (Lake of the Woods/Rainy River and Southern Hudson Bay/James Bay) to be of "special concern" (COSEWIC 2006).

CRITERIA FOR ENDANGERED SPECIES ACT LISTING

Under the Endangered Species Act, 16 U.S.C. § 1533(a)(1), the USFWS is required to list a species for protection if it is in danger of extinction or threatened by possible extinction in all or a significant portion of its range. In making such a determination, the USFWS must analyze the species' status in light of five statutory listing factors (16 U.S.C. § 1533(a)(1)(A)-(E); 50 C.F.R. § 424.11(c)(1) - (5)):

(A) the present or threatened destruction, modification, or curtailment of its habitat or range;

(B) overutilization for commercial, recreational, scientific, or educational purposes;

(C) disease and/or predation;

(D) the inadequacy of existing regulatory mechanisms;

(E) other natural or manmade factors affecting its continued existence.

A species is "endangered" if it is "in danger of extinction throughout all or a significant portion of its range" due to one or more of the five listing factors. 16 U.S.C. § 1531(6). A species is "threatened" if it is "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." 16 U.S.C. § 1531(20).

Imperiled U.S. Populations of Lake Sturgeon Qualify As "Species" Under the ESA

The Endangered Species Act provides for the listing of all species warranting the protections afforded by the Act. The term "species" is defined broadly under the Act to include "any subspecies of fish or wildlife or plants and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." 16 U.S.C. §1532 (16). A distinct population segment of a vertebrate species can be protected as a "species" under the Endangered Species Act even though it has not formally been described as a separate "species" or "subspecies" in the scientific literature. A species may be composed of several distinct population segments, some or all of which warrant listing under the Endangered Species Act. The taxonomic data discussed in this petition indicates that there may be distinct population segments of lake sturgeon in the United States that warrant protection under the Act.

Under the USFWS's "Policy Regarding the Recognition of Distinct Vertebrate Population Segments under the Endangered Species Act" (Fed. Reg. 61: 4721), three elements are considered in a decision regarding the status of a possible distinct population segment as endangered or threatened under the Act:
1) Discreteness of the population segment in relation to the remainder of the species to which it belongs;
2) The significance of the population segment to the species to which it belongs; and
3) The population segment's conservation status in relation to the Act's standards for listing.

For a population segment of a vertebrate species to be considered discrete, it must satisfy either of the following conditions:

1) It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors (quantitative measures of genetic or morphological discontinuity may provide evidence of this separation); or
2) It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act. (Fed. Reg. 61: 4725).

According to the Service's distinct population segment policy (Fed. Reg. 61: 4725), once a population is established as discrete, its biological and ecological significance should then be considered. This consideration may include, but is not limited to, the following:
1) Persistence of the discrete population segment in an ecological setting unusual or unique to this taxon;
2) Evidence that loss of the discrete population would result in a significant gap in the range of a taxon;
3) Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historical range; and
4) Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

<u>Lake Superior Sturgeon Are Discrete and Significant</u>

Lake sturgeon in Lake Superior and its tributaries are discrete because they are physically separated from all other lake sturgeon populations, including those sturgeon in the rest of the Great Lakes. The St. Marys River is the sole outflow of Lake Superior, draining into Lake Huron. There are rapids in the upper St. Marys River's at the Lake Superior end with a steep gradient and a 25-foot height difference between Lakes Superior and Huron. The Soo Locks were built to enable ships to bypass the rapids, but these locks, the Edison Sault hydroelectric canal, and the St. Marys Rapids compensating works form a migration barrier that limits movement of lake sturgeon between the upper and lower St. Marys River (Gerig et al. 2011), separating Lake Superior sturgeon from Lake Huron sturgeon and the rest of the Great Lakes. Although flows are diverted from the Okogi River in the Hudson Bay drainage into Lake Nipigon in the Nipigon River tributary of Lake Superior, there is no connection between these drainages through which lake sturgeon can migrate. Based on the studies discussed above (DeHaan et al. 2006; COSEWIC 2006; Welsh et al. 2008; Welsh et al. 2010), lake sturgeon in Lake Superior and its tributaries differ markedly in their genetic characteristics from other populations of lake sturgeon. They also inhabit the largest of the Great Lakes and the largest body of fresh water on earth. Collectively, these factors make Lake Superior lake sturgeon ecologically significant. Lake Superior lake sturgeon qualify as a distinct population segment under USFWS policy.

<u>Western Lake Michigan Sturgeon May Be Discrete and Significant</u>

Lake sturgeon in western Lake Michigan are discrete because they are reproductively isolated from lake sturgeon populations in the rest of the Great Lakes. Although lake sturgeon in Lake Michigan and its tributaries have connection through the Straits of Mackinac to sturgeon in Lake Huron (which in turn is connected to Lake Erie through the St. Clair River, Lake St. Clair and the Detroit River), sturgeon in western Lake Michigan do not appear to interbreed with those in Lake Huron or Lake Erie, even though genetic differentiation between populations in these three lakes is low. Scribner et al. (2004) found that lake sturgeon populations in Lake Michigan tributaries differ genetically from populations in Lake Huron tributaries, but not many populations were included in the analysis. Lake sturgeon in eastern Lake Michigan have fairly low levels of genetic distinction between them and sturgeon in the lower Great Lakes (Welsh et al. 2010).

Evidence for distinct genetic assemblages and an argument for a discrete and significant lake sturgeon population in western Lake Michigan comes from Scribner et al. (2004), who found that lake sturgeon populations in western Lake Michigan tributaries to Green Bay (Menominee, Peshtigo, Oconto, Fox, and Wolf rivers) were genetically more similar to each other than to populations in eastern Lake Michigan (Manistee and Muskegon rivers). Homola et al. (2012) identified 6 genetically differentiated spawning populations of lake sturgeon in rivers tributary to Lake Michigan, in the Fox, Menominee, Oconto–Peshtigo, Kalamazoo, Manistee and Muskegon rivers. Significantly, although Homola et al. (2012) found high straying rates of lake sturgeon between the different Lake Michigan river systems, the genetic data suggest that either individual sturgeon that stray are reproductively unsuccessful or that contemporary straying rates are not reflective of historical rates of gene flow.

<u>Northwestern Minnesota Sturgeon Are Discrete and Significant</u>

Lake sturgeon in the Red River basin in Northwestern Minnesota are discrete because of their isolated geographic location, the long-standing presence of numerous dams that have been barriers to migration for more than 100 years, and the lack of other large spawning populations within the Lake Winnipeg basin. Lake Winnipeg drains northward into the Nelson River and forms part of the Hudson Bay watershed, distinct from the Great Lakes. Lake sturgeon in the upper Red River and its tributaries in Northwestern Minnesota are extremely unlikely to have any interchange with any other lake sturgeon populations. More than 500 dams have been built in the Red River basin since the late 1800s, blocking lake sturgeon in Lake Winnipeg from access to most U.S. tributaries by the 1870s (Aaland et al. 2005). By the early 2000s there was no evidence of naturally reproducing sturgeon populations in the major watersheds of the Assiniboine or Red Rivers, and lake sturgeon were extremely rare in the Canadian portion of the Red River from Lake Winnipeg to the American border (COSEWIC 2006). A number of smaller tributaries to Lake Winnipeg in Canada (Pigeon, Bloodvein, Poplar and Berens rivers) supported lake sturgeon, but spawning females were unlikely to exceed 100 annually in any component (COSEWIC 2006), and these fish would have no way to interact with sturgeon in the upper Red River basin.

Lake sturgeon in Rainy Lake/Rainy River/Lake of the Woods in Northwestern Minnesota are also discrete because of their isolated geographic location and the influence of dams. Lake of the Woods-Rainy River sturgeon are genetically distinct from fish from the Winnipeg River, even though this system ultimately drains into the Winnipeg River (COSEWIC 2006). Falls and dams along the Winnipeg River, particularly the Norman Dam located at the mouth of the river, impede passage of sturgeon from Lake of the Woods and prevent upstream movement. Although it is unlikely that the pre-dam rapids at Norman prevented movement of lake sturgeon, falls lower down on the system probably did (COSEWIC 2006). There are no genetic data available for lake sturgeon upstream of the Rainy River in Rainy Lake.

Lake sturgeon in the Red River basin and Rainy Lake/Rainy River/Lake of the Woods in Northwestern Minnesota are also discrete because their watersheds are bisected by the Canada-U.S. international boundary, with differences in control of exploitation and conservation status on either side of the border. The province of Manitoba allows only catch-and-release angling for lake sturgeon (MDNR 2012), whereas Minnesota allows anglers, with certain conditions, to harvest one lake sturgeon per year from Minnesota-Canada border waters (MNDNR 2016b). The lake sturgeon is designated only as a "species of concern" in Minnesota (MNDNR 2016a), which does not provide any formal or substantive protections, whereas Canada designated the Red-Assiniboine Rivers/Lake Winnipeg population of lake sturgeon as "endangered" and the Lake of the Woods-Rainy River population as "special concern" in 2006 (COSEWIC 2006). Based on an analysis of genetic studies and aquatic ecozones, Canada identified "designatable units" or distinct population segments of lake sturgeon in Red-Assiniboine Rivers/Lake Winnipeg and Lake of the Woods-Rainy River, which differ markedly from all other populations (COSEWIC 2006). The Red-Assiniboine Rivers/Lake Winnipeg unit includes lake sturgeon in Lake Winnipeg, the Red River basin, the Assiniboine River and all eastern tributary rivers to Lake Winnipeg except for the Winnipeg River; the Lake of the Woods-Rainy River unit includes lake sturgeon in all Rainy River and Lake of the Woods tributaries upstream of Kenora (COSEWIC 2006). The USFWS should determine whether lake sturgeon in the Red River basin and Rainy Lake/Rainy River/Lake of the Woods in Northwestern Minnesota qualify as one or more distinct population segments under USFWS policy.

Upper Mississippi River Sturgeon Are Discrete and Significant

Lake sturgeon in the upper Mississippi River basin are discrete because they are geographically isolated from all other lake sturgeon populations. The only remaining naturally spawning populations of lake sturgeon in the upper Mississippi River basin are in tributaries in Minnesota, Wisconsin and Illinois, far from any other viable lake sturgeon populations in the entire Mississippi River watershed. The other nearby lake sturgeon population of any significance is one small population far up a tributary in the Ohio River sub-basin; there are very few remaining lake sturgeon in the middle or lower reaches of the Mississippi river downstream of the Ohio River confluence, and very few sturgeon in the Missouri River sub-basin. Additionally, numerous dams on the Mississippi River and its upper tributaries block any of these sturgeon from interacting, as sturgeon are isolated above and below these dams. Although very little is known about the historical genetic composition of lake sturgeon native to the Mississippi River basin (Drauch and Rhodes 2007), a genetic study has shown that lake sturgeon from the upper Mississippi River basin diverge significantly from lake sturgeon in Hudson Bay and the Great Lakes; more importantly they are also significantly differentiated from those in the Ohio River sub-basin (Drauch et al. 2008). This supports the presumption that lake sturgeon populations occurring in different major drainages appear invariably to be genetically distinct from each other (COSEWIC 2006). Lake sturgeon in the upper Mississippi River basin are significant because loss of this population would essentially eliminate viable, naturally occurring populations from the entire Mississippi River basin, and would result in a significant gap in the range of the lake sturgeon. Viable naturally reproducing lake sturgeon populations only occur in the St. Croix, Chippewa, and Wisconsin river systems in the upper Mississippi River basin – aside from a very distant and small isolated population in the East Fork of the White River in the Ohio River sub-basin, there are no other significant, self-sustaining, naturally occurring lake sturgeon populations in the entire Mississippi River basin. Upper Mississippi River basin lake sturgeon qualify as a distinct population segment under USFWS policy.

Missouri River Sturgeon Are Discrete and Significant

The few indigenous lake sturgeon remaining in the Missouri River basin are discrete because they are geographically isolated from all other lake sturgeon populations, even within the Mississippi River basin. They are far from naturally spawning populations in the upper Mississippi River basin and from a small population in a tributary in the Ohio River sub-basin, and are blocked by dams from interacting with other sturgeon in the Mississippi River drainage. The study by Drauch et al. (2008) showing that lake sturgeon in other major sub-basins of the Mississippi River (upper Mississippi River and Ohio River) are genetically distinct suggests that there may also be evolutionary independence for naturally occurring lake sturgeon from the Missouri River basin. Stocking of lake sturgeon is occurring the Missouri River, using fish from out of the basin (Lake Winnebago). The Missouri River is the longest river in North America and the drainage basin comprises more than half a million square miles – the loss of lake sturgeon from the basin would be ecologically significant and result in a significant gap in the range of the species. Missouri River basin lake sturgeon qualify as a distinct population segment under USFWS policy.

Ohio River Sturgeon Are Discrete and Significant

Lake sturgeon in the Ohio River basin are discrete because they are geographically isolated from all other lake sturgeon populations. The only remaining naturally spawning populations of lake sturgeon in the Ohio River basin are in the East Fork of the White River, a tributary of the Wabash River in southern Indiana, far from any other viable lake sturgeon populations in the entire Mississippi River watershed. A genetic study has shown that lake sturgeon from the Ohio River sub-basin diverge significantly from lake sturgeon in Hudson Bay and the Great Lakes; more importantly they are also significantly differentiated from those in the upper Mississippi River basin (Drauch et al. 2008). Lake sturgeon in the East Fork of the White River are significant because loss of this population would essentially eliminate viable, naturally occurring populations from the entire Ohio River basin. Ohio River basin lake sturgeon qualify as a distinct population segment under USFWS policy.

Arkansas-White River Sturgeon Are Discrete and Significant

Very little is known about lake sturgeon within Arkansas and there have been only a handful of recent sightings of lake sturgeon in the White River (Buchanan et al. 1993). The state of Arkansas has designated lake sturgeon as a species of special concern due to its rarity (AGFC 2013). If there are still naturally occurring populations of lake sturgeon in the Arkansas-White River basin, they would be discrete because they are geographically isolated from all other lake sturgeon populations. The study by Drauch et al. (2008) showing that lake sturgeon in other major sub-basins of the Mississippi River (upper Mississippi River and Ohio River) are genetically distinct suggests that there may also be evolutionary independence for any naturally occurring lake sturgeon from the Arkansas-White River basin. If the species still persists, any Arkansas-White River basin lake sturgeon would qualify as a distinct population segment under USFWS policy.

Lower Mississippi River Sturgeon Are Discrete and Significant

There is little historical information on lake sturgeon in the lower Mississippi River basin, and there have been no recent records. Lake sturgeon were known to have formerly occurred in the lower Mississippi River in Tennessee, as well as the Caddo River and Little Missouri River tributaries of the Ouachita River in Arkansas. Stocking of lake sturgeon is occurring in the lower Mississippi River in Louisiana, using fish from out of the basin (Lake Winnebago). If there are still naturally occurring populations of lake sturgeon in the lower Mississippi River basin, they would be discrete because they are geographically isolated from all other lake sturgeon populations. The study by Drauch et al. (2008) showing that lake sturgeon in other major sub-basins of the Mississippi River (upper Mississippi River and Ohio River) are genetically distinct suggests that there may also be evolutionary independence for any naturally occurring lake sturgeon from the lower Mississippi River basin. If the species still persists, any lower Mississippi River basin lake sturgeon would qualify as a distinct population segment under USFWS policy.

The conservation status and threats to these lake sturgeon populations in relation to the 5 listing factors are discussed in detail below.

U.S. Lake Sturgeon Populations Are Endangered or Threatened Under the ESA

The USFWS is required to determine, based solely on the best scientific and commercial data available, whether a species or distinct population segment is endangered or threatened because of any of the following factors: (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting its continued existence. 16 U.S.C. §1533(a)(1) and 1533(b).

As discussed below, this petition will demonstrate that all of these factors except disease and predation have played a role in bringing the U.S. populations of lake sturgeon to their current perilous condition. This petition demonstrates that potentially distinct populations of the lake sturgeon are in danger of extinction or threatened by possible extinction; and that the entire species of lake sturgeon is threatened by possible extinction. U.S. populations of lake sturgeon warrant protection as endangered or threatened under the Endangered Species Act due to impacts from dams and hydroelectric facilities, pollution and contaminants, dredging and channelization, historical legacy of overfishing, poaching, invasive species, climate change, habitat fragmentation, vulnerable life history characteristics, lack of population viability, and compromised genetic integrity.

Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Dams and Hydroelectric Facilities

Of all the current threats to lake sturgeon and their habitat, impacts from dams are one of the most significant (Pratt 2008, p. 28). Dam construction has often preceded declines in local sturgeon populations (Granado-Lorencia 1991; Zhong and Power 1996; Jager 2006a). Dams and hydroelectric facilities harm lake sturgeon and are a threat to imperiled lake sturgeon populations in a numbers of ways: they block lake sturgeon migration to suitable spawning, nursery and foraging habitat; cause loss of spawning and nursery habitat; alter water flows during critical sturgeon life stages; alter thermal regimes in rivers; fragment and isolate sturgeon populations; entrain sturgeon; alter predator/prey relationships; and deplete sturgeon food sources. Dams and hydroelectric facilities are known to block lake sturgeon migration routes to historic spawning grounds, degrade critical downstream habitats, cause habitat fragmentation, and separate life stages of sturgeon (COSEWIC 2006, p. 4; Harkness and Dymond 1961; Priegel and Wirth 1971; Auer 1996a; Wilson and McKinley 2004, Peterson et al. 2007, p. 59; Kerr et al. 2011, pp.4-8). Regulated flow regimes caused by dams and hydroelectric facilities are one of the most serious and continuing threats to ecological sustainability of rivers (Bunn and Arthington 2002, p. 492). Besides acting as a physical barrier, dams alter patterns of nutrient transport, ecological structure, and water temperature, flow and chemistry (MacDonell 1995; Bednarek 2001; Threader et al. 2005; Haxton and Findlay 2009; Mora et al. 2009), which can affect opportunities for lake sturgeon spawning and recruitment (Jager et al. 2001).

Migration Barriers

Construction of dams creates barriers to lake sturgeon migration (Auer 1996a, p. 155), effectively eliminating significant areas of spawning habitat for lake sturgeon in many river systems (Hay-Chmielewski and Whelan 1997, p. 31). Barriers deny use of spawning habitat by preventing upstream movement and by burying high-gradient habitat under impoundments (Hay-Chmielewski and Whelan 1997, p. 31). Hydroelectric developments harm sturgeon by maintaining impediments or barriers preventing access to upstream spawning or foraging sites (Ferguson and Duckworth 1997, p.303; Haxton 2002; Knights et al. 2002; Friday 2005; Daugherty et al. 2008). Hydropower and pulp and paper mill dams, many of which were built in the early 1800s, continue to block many major lake sturgeon spawning migration routes in the Great Lakes (Auer 1996a, pp. 155,157). The movements of most remaining lake sturgeon populations in the United States are severely restricted by dams, hydroelectric facilities or navigation locks (Folz and Meyers 1985; Thuemler 1985; Hay-Chmielewski 1987; Mosindy 1987). For example, most of Michigan's larger rivers are impounded, including 90% of larger Great Lakes tributaries, and usually the first barrier is located on the first high gradient reach inland from the Great Lakes (Hay-Chmielewski and Whelan 1997, p. 31). Loss of potamodromous habitat to impoundments in Michigan 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 (Hay-Chmielewski and Whelan 1997, p. 31). Construction of hydroelectric dams and other barriers to migration were responsible for huge declines in lake sturgeon abundance throughout the 1930s in Lake Superior (Auer 2003, p. 4). Barriers to migration can also affect the genetic integrity of sturgeon populations, which may result in a population being less able to withstand future environmental stresses (Ferguson and Duckworth 1997, pp. 303-304; Rieman and Allandorf 2001).

Habitat Loss

Construction of dams causes a loss of sturgeon spawning and nursery habitat by inundation or by blocking access (Auer 1996). Because of dams, many historic spawning grounds are now either inaccessible or unusable; without adequate spawning habitat in which to continue the reproductive cycle, all other preserved sturgeon habitats serve little purpose (Houston 1987, p. 183).

Population Fragmentation

Natural barriers, such as fast flowing rapids or small waterfalls, may not fragment lake sturgeon habitat or population connectivity (Welsh and McLeod, 2010), however artificial barriers such as hydroelectric developments or water diversions have resulted in severely fragmented habitats, isolated populations, and altered spawning behavior (Paragamian et al. 2001; Haxton, 2002; Daugherty et al. 2008a, 2008b). Barriers to sturgeon migration also prevent the use of optimal habitats for each lake sturgeon life stage (Hay-Chmielewski and Whelan 1997, p. 31). Extensive damming has immediate impacts on lake sturgeon, as it reduces potential range sizes and fragments existing populations (Ferguson and Duckworth 1997; Cooke et al. 2002; Dadswell 2006). Auer (1996) estimated that lake sturgeon may require 250 to 300 km of unimpeded river-lake habitat as a minimum home range size to complete their life cycle, without which populations may become vulnerable to extirpation when habitat is severely impacted or unreachable (Harkness and Dymond 1961; Baker and Borgeson 1999). The effects of habitat fragmentation can be delayed, as lake sturgeon populations occupying impounded sections of rivers have lesser abundance and slower growth rates compared to populations residing in unimpeded stretches of rivers (Haxton, 2002, 2003a; Haxton and Findlay 2008). Fragmentation of lake sturgeon populations by dams is known to erode the genetic diversity in fish populations (Ferguson and Duckworth 1997, pp. 303-304; Rieman and Allandorf 2001). Isolation of sturgeon populations also makes them vulnerable to extinction (Jager et al. 2001), as confined stocks are at greater risk of extirpation from disease, impacts of pollution or natural catastrophic events (Auer 1999, p. 291).

Flow Alteration

Construction and operation of dams obviously changes the natural flow patterns of rivers, often to the detriment of lake sturgeon (Auer 1996). Hydroelectric dams and developments harm lake sturgeon by reducing or altering spring flows (Zhong and Power 1996a; Haxton 2002), reducing spawning success and recruitment (Ferguson and Duckworth 1997, p.303; Caroffino et al. 2010), altering thermal regimes (Zhong and Power 1996a; Paragamian et al. 2001; Horne et al. 2004; Kappenman et al. 2009) and reducing water quality (Zhong and Power 1999).

Reservoir management and manipulation of river flows can have a significant impact on lake sturgeon adults, juveniles and eggs (Pratt 2008, p. 28). Changes in the annual hydrologic profile can affect the cues used to trigger spawning in lake sturgeon (Harkness and Dymond 1961; Auer 1994). Low water levels, variable water temperatures and low oxygen concentrations can negatively affect sturgeon spawning and success of embryo survival.

Hydro-peaking is the practice by which hydropower companies hold back water during off-peak hours and release more water during peak hours to maximize profit. The “peaking” operation regime at hydroelectric facilities has been attributed to lowered biological diversity downstream (Cushman 1985). This practice can be devastating to lake sturgeon eggs since, in many documented cases, sturgeon release their eggs during high flows at peak hours and eggs can consequently dry-up at low flow during off-peak hours (USFWS 2016b). Peaking can also reduce or eliminate night time water flows, impacting the downstream drift of larval lake sturgeon and impairing larval recruitment (Haxton and Findlay 2009). Rapid flow decreases may also result in stranding fish on gravel bars or off-channel habitats (Bunn and Arthington 2002, p. 495). Sturgeon may be attracted to pools at the base of dams and similar features, trapping them there when water levels rapidly subside (Young and Love 1971; Brousseau and Goodchild 1989; Friday 2004). Flow manipulation caused by dams and hydroelectric facilities is known to affect all life stages of sturgeon, but it most adversely affects age-0 sturgeon and sturgeon eggs (Pratt 2008, p. 28), which limit many recovery efforts.

Other impacts of peaking operation include: flushing of riverine reaches with flood flows during peak power periods; reducing the algal and aquatic plant life which are important food for aquatic insects and provide fish nursery areas, by dewatering riverine habitat; reducing fish growth and survival by reducing available habitat; changing the benthic invertebrate community to smaller and less useful fish foods; and causing downstream erosion and sedimentation which destroys fish habitat and can disrupt fish migratory patterns (MDNR 1994).

Multiple studies have documented significant negative impacts from peaking operations that destabilize daily flow patterns on riverine systems, including reductions in river productivity and recruitment failure in stream fishes (Cushman 1985; Gislason 1985; Nelson 1986; Bain and Finn 1988). Instream flow studies by the Michigan Department of Natural Resources on hydropower projects in Michigan support these studies, documenting habitat losses up to 99% for non-mobile life stages and species (i.e. spawning, incubating eggs, fry and benthos) and between 40-70% for mobile life stages and species (i.e. juvenile and adult fish) for projects proposing full peaking operation (MDNR 1994).

Conversely, studies document a significant change in behavior and population characteristics in the spawning run of lake sturgeon when a project was converted to run-of-river, including: increase in the average size of lake sturgeon; increase in spawning readiness; decrease in the amount of time spawning fish remain in the river (thus decreasing their exposure to adverse conditions and poaching); and increase in the overall size of the spawning run (Auer 1987, 1988, 1989, 1990). Changing hydroelectric dam operations from peaking mode (which causes large daily fluctuations in river flows) to run-of-the-river (which more closely mimic natural flows) improves conditions for lake sturgeon spawning below dams (Auer 1996b, pp.69-76).

Lake sturgeon migrate in order to optimize reproductive success (McKeown 1984). Consistent water flows that maintain water depth during spawning season give larger fish (meaning more females) easier access to the spawning rapids, which should increase egg production and spawning success. River flow regimes under peaking are contrary to these needs. Regulated river flows may also inhibit post-spawning rapid downstream movement of sturgeon, which may be necessary to avoid stranding, exposure to direct sunlight, and predators as spring river flows decline, and to find food and rest; this may also be an adaptation that removes feeding adults from areas where eggs and newly-hatched young are concentrated (Auer 1999, p. 291). Since food and protective cover are not found on spawning grounds, adults may gain some advantage by minimizing their time there.

Even with run-of-the-river projects, reservoirs alter water quality, and aquatic life below dams is different from un-impounded reaches (MDNR 1994). Projects that divert water around river reaches or from one river basin to another dewater the bypassed river reaches and change the natural flow pattern of the bypassed river reach, causing: direct loss of aquatic habitat by drying up large sections of rivers; disruptive changes in fish behavior which waste energy, altered migratory patterns and curtailed reproductive activities; negative benthic organism community composition changes; loss of key high gradient habitat areas; and decreased overall productivity of the system (MDNR 1994).

Changes to River Ecology

Natural river flow regimes are important for maintaining healthy and productive river communities (Noakes et al. 1999). Construction of dams changes river community structure and ecology (R.L.&L. 1992; Auer 1996). Dam operations can affect food availability, nutrient status, and predator/prey relationships for sturgeon (Noakes et al. 1999). Dams have been shown to alter the abundance, composition, and diversity of benthic macroinvertebrates, an important food source for lake sturgeon (Fisher and LaVoy 1972; Troelstrup and Hergenrader 1990; Weisberg and Burton 1993; McKinley et al. 1993; Snyder and Minshall 2005). Macroinvertebrate communities are typically species-poor in regulated river reaches below hydroelectric facilities (Munn and Brusven 1991; Bunn and Arthington 2002, p. 495). Dam outflows can warm a river during winter and cool it during summer, resulting in the seasonal temperature requirements of many invertebrates not being met and large-scale macro-invertebrate depletion, which is common downstream of dams (Lehmkuhl 1972). Since invertebrates are an important food source for lake sturgeon, low prey densities make foraging difficult and can have detrimental effects on the growth rates of sturgeon (Chiasson et al.1997). Changes in flow and sediment distribution also alter macrobenthos abundance (Trotzky and Gregory 1974) and have detrimental effects on the growth and reproduction of lake sturgeon (Chiasson et al. 1997). Altered aquatic systems also develop a new array of prey, predators and competitors (Beamesderfer and Farr 1997).

Entrainment

Hydroelectric developments harm sturgeon by entrainment and subsequent turbine mortality (Seylor 1997a, 1997b; Hay-Chmielewski and Whelan 1997, p. 34). Fish are directly impacted by turbines, and in some cases spillways (MDNR 1994). Dam turbine mortalities can have a significant impact on lake sturgeon adults, juveniles and eggs (Pratt 2008, p. 28). Fish entrainment and turbine mortality has always been a problem and an issue of concern at hydroelectric power plants throughout the Midwest (USFWS 2016b). Numerous studies conducted at hydropower dams in Wisconsin have shown that thousands of fish are entrained annually and that many of these fish are killed by the turbines (USFWS 2016b). Studies on anadromous fish from both the Pacific and Atlantic coasts show mortalities of between 5-90% at each facility (Eicher et al. 1987). Several dozen studies conducted in Michigan provided entrainment and mortality estimates for hydroelectric facilities: a mean project entrainment range of 60 to 4,566 fish; mean project mortality of 3 to 48%; and a range of 1,363 to 351,887 fish lost per project per year (MDNR 1994). The Michigan Department of Natural Resources found no relationships between project characteristics and entrainment, and significant unit to unit variation in numbers and species entrained, so there is no way to predict entrainment (MDNR 1994).

Water Quality

Hydroelectric facilities impact aquatic resources by changing the water quality characteristics of river systems. The major problem areas are: low dissolved oxygen from dam releases, which usually occurs in stratified reservoirs with deep hydro intakes; temperature changes from the ponds acting as heat sinks; changes in groundwater inputs to the river system which also change the temperature of the system; mobilization of contaminants which can occur in stratified lakes; and changes in nutrients and the type and amount of entrained plankton (MDNR 1994). Impounded water bodies resulting from dams can lead to contamination, since the flooding of naturalized terrestrial areas and the further decomposition of organic matter causes increased production of methyl-mercury, a well-known environmental toxicant, which contaminates nearby fish populations and those located downstream (Stokes and Wren 1987; Grondin et al. 1995; Zhong and Power 1996b).

Great Lakes Sturgeon Are Threatened by Dams and Hydroelectric Facilities

There are more than 7,000 dams on tributaries of the Great Lakes, only 36% of which are fully passable for fish (Januchowski-Hartley et al. 2013, p. 4). In the state of Michigan alone there were 103 hydroelectric facilities operating as of 1994, impacting 49 river systems (including almost every major river system in Michigan), and preventing anadromous fish movement into at least 2,063 miles of mainstem rivers, dewatering 57 river miles, directly impounding 623 river miles and impacting habitat in 733 river miles through their operations (MDNR 1994, p. 1).

Lake Superior Sturgeon Are Threatened by Dams and Hydroelectric Facilities

In the Ontonagon River, Victoria Dam blocks lake sturgeon access to historic spawning grounds, 8 km upstream from Lake Superior (Auer 1996a). Rapid water temperature changes (up to 10° C changes in 10 minutes) detrimental to lake sturgeon have been documented at the Bond Falls hydroelectric project on the Ontonagon River (MDNR 1994).

In the Sturgeon River, Prickett Dam blocks lake sturgeon access to historic spawning grounds, 69 km upstream from Lake Superior (Auer 1996a). Significant deviations from water quality temperature standards have been documented for the Prickett Project on the Sturgeon River (MDNR 1994).

Western Lake Michigan Sturgeon Are Threatened by Dams and Hydroelectric Facilities

The lake sturgeon population in Indian Lake was landlocked and had access from Lake Michigan blocked by construction of dams on the Manistique River and Indian River downstream from Indian Lake (Baker 1980; Galarowicz 2003). Lake sturgeon in Indian Lake, which spawn in the upper reaches of the Indian River, could move downstream to Lake Michigan but could not return beyond the lower dam on the Manistique River (Bassett 1981).

In the Menominee River there are now 11 hydroelectric dams which prevent lake sturgeon in Lake Michigan from migrating up the river to get to prime spawning and rearing habitat (Donofrio and Utrup 2013), including the Menominee, Park Mill, Grand Rapids, White Rapids and Chalk Hill hydroelectric dams (Coscarelli et al. 2011). Lake sturgeon currently can only migrate less than 4 km upstream in the Menominee River from Lake Michigan, where passage is blocked by the Upper Scott Paper Company Dam, built in 1924 at the base of a high gradient stretch of river (Auer 1996a; Thuemler 1997; Donofrio and Utrup 2013). More than 70% of the high-gradient habitat once used by lake sturgeon in the Menominee River is now impounded (Thuemler and Schnicke 1992). Daugherty et al. (2009) determined that only 6.4 km (10%) of the 64 km of high quality spawning habitat in various reaches of the Menominee River is available to lake sturgeon; 90% is blocked by dams and only 3 km (4%) of the river's age-0 juvenile habitat is available to lake sturgeon.

In the Peshtigo River, lake sturgeon access to historic spawning grounds is blocked by Peshtigo Dam and migrations now are limited to the 12 km stretch of river above Green Bay and below Peshtigo Dam (Auer 1996a; Elliott and Gunderman 2008). Daugherty et al. (2009) determined that 97% of the high quality spawning habitat for lake sturgeon in the Peshtigo River is blocked by the Peshtigo and Potato Rapids dams. Juvenile lake sturgeon in the Peshtigo River historically had 60 river km or more to use as nursery habitat but now have access to less than one-third of this amount (Caroffino et al. 2010b).

In the Oconto River, lake sturgeon access from Lake Michigan to historic spawning grounds is blocked by Oconto Falls Dam, 6 km upstream from Lake Michigan (Auer 1996a). No lake sturgeon now exist upstream of Stiles Dam at river km 22 (Elliott and Gunderman 2008). Daugherty et al. (2009) determined that 89% of the high quality spawning habitat for lake sturgeon in the Oconto River is blocked by Stiles Dam.

In the Fox River, Daugherty et al. (2009) determined that 84% of the high quality spawning habitat for lake sturgeon in the lower river is blocked by the Rapide Croche Dam and Lower Kaukauna Dam. De Pere hydroelectric dam also blocks historical lake sturgeon spawning or nursery habitat (Coscarelli et al. 2011). Lake sturgeon access to historic spawning grounds in the upper Fox River has been blocked by 14 locks and 17 dams (Auer 1996a).

In the Wolf River, lake sturgeon historically migrated upstream to spawn at Keshena Falls, which was blocked by construction of two dams downstream in the late nineteenth and early twentieth centuries (Runstrom et al. 2002). The Shawano and Balsam Row hydroelectric dams block historical lake sturgeon spawning and nursery habitat (Coscarelli et al. 2011). Spawning now occurs upstream to Shawano (WDNR 2012), but lake sturgeon are extirpated from above Keshena (Zollweg et al. 2013). Rapid flow decreases have been documented on the Wolf River from dam operation, which desiccated lake sturgeon embryos after they were dislodged from the river substrate and exposed to the air (Kempinger 1988).

Lake sturgeon spawned in the Milwaukee River in the 1800s, but by 1850 a dam built about 5 miles upstream from Lake Michigan prevented adult sturgeon from making it upstream to their spawning grounds (Brunner and Alexander 2013).

On the Escanaba River, significant deviations from water quality temperature standards have been documented for the Boney Falls hydroelectric project (MDNR 1994).

Eastern Lake Michigan Sturgeon Are Threatened by Dams and Hydroelectric Facilities

When Niles Dam was built on the St. Joseph River in 1868, migrating lake sturgeon could no longer move upstream; trapped and valuable to the local economy, sturgeon numbers began to plummet after just ten years (Wesley and Duffy 1999, p. 55). There are now 190 dams in the St. Joseph River watershed, 17 of which are on the mainstem; as a result sturgeon are cut off from 155 river miles of former spawning habitat (Wesley and Duffy 1999, p. 55). Before construction of dams on the St. Joseph River, lake sturgeon had access to suitable spawning habitat as far upstream as Hillsdale County at river km 286; they are now limited to spawning immediately below Berrien Springs Dam at river km 37, which blocks upstream migration into historic habitat (Auer 1996a; Wesley and Duffy 1999; Coscarelli et al. 2011).

In the Kalamazoo River the Allegan hydroelectric dam blocks historical lake sturgeon spawning and nursery habitat (Coscarelli et al. 2011).

Construction of Newaygo Dam in the Muskegon River in 1900 blocked upstream passage of lake sturgeon to the only high gradient portions of the Muskegon River with suitable spawning habitat (Peterson and Vecsei 2004). Although Newaygo Dam was demolished in 1968, sturgeon migration continues to be blocked by Croton Dam, 67 km upstream from Lake Michigan (Auer 1996a; Wieten 2013). Both Croton and Hardy hydroelectric dams block historical lake sturgeon spawning and nursery habitat (Coscarelli et al. 2011).

In the Manistee River Tippy Dam, a large hydroelectric facility completed in 1918 and located 45 km upstream from Lake Michigan, blocks lake sturgeon migration into historic spawning grounds (Auer 1996; Coscarelli et al. 2011), as does Hodenpyl hydroelectric dam (Coscarelli et al. 2011). Data from hydroelectric dam projects on the Manistee River have demonstrated violations of the state water quality standard for dissolved oxygen (MDNR 1994). Significant deviations from temperature standards have been documented for the Tippy Dam Project on the Manistee River (MDNR 1994).

Northwestern Minnesota Sturgeon Are Threatened by Dams and Hydroelectric Facilities

In the Red River, the mainstem of the river has 9 dams, and a staggering number - more than 500 dams - have been constructed on tributaries in the U.S. portion of the basin (Aaland et al. 2005, p. 296). Most U.S. tributaries of the Red River that have suitable lake sturgeon spawning habitat had been blocked by dams by the 1870s (Aaland et al. 2005, p. 298). The St. Andrews Dam in Canada (which has a fish ladder inadequate to pass lake sturgeon) prevents Lake Winnipeg sturgeon from reaching any remaining rapids and spawning areas in the Red River basin; and the Red River Floodway Control Structure in Manitoba may also be a barrier to upstream sturgeon movement (Aaland et al. 2005, pp. 298-299).

Since 1994, the Minnesota Department of Natural Resources and other agencies have begun efforts to remove or modify dams within the Red River basin to restore sturgeon passage (Aaland et al. 2005, p. 299; Abraham and Kallak 2008, p. 13). Five of the 8 U.S. dams on the mainstem of the Red River have been modified for sturgeon passage and 19 dams have been modified or removed on tributaries (Abraham and Kallak 2008, p. 13). Removal of the Buffalo State Park Dam from the Buffalo River and the failure of the Hieberg Dam on the Wild Rice River have restored sturgeon access to high quality spawning habitat (Aaland et al. 2005, p. 308). Hieberg Dam was subsequently modified to restore sturgeon passage into the upper reaches of the Wild Rice River and White Earth Lake (Abraham and Kallak 2008, pp. 9-10, 13). There are plans to modify or remove 20 more dams in the Red River basin to provide passage for sturgeon (Abraham and Kallak 2008, p. 14). On the Red Lake River, removal of the Crookston Dam and conversion of the East Grand Forks Dam to rapids are planned (Aaland et al. 2005, p. 308).

However, the success of lake sturgeon recovery in the entire basin depends upon addressing the barrier created by St. Andrew's Dam at Lockport, to connect the Red River to Lake Winnipeg and provide year-round sturgeon passage (Aaland et al. 2005, p. 308). Also, the Red River basin faces threats of additional dam construction, such as a 20-foot dam proposed on the Wild Rice River tributary (Aaland et al. 2005, pp. 307-308).

Rainy River is controlled at its outflow from Rainy Lake by a hydroelectric dam built in 1909. Lake sturgeon in Rainy Lake have been segregated from upstream Namakan Lake and downstream Lake of the Woods/Rainy River system sturgeon populations by dams constructed on the outlets of Rainy and Namakan lakes early in the 20th century (Adams et al. 2006a).

Upper Mississippi River Sturgeon Are Threatened by Dams and Hydroelectric Facilities

In the Mississippi River basin, dams without locks completely block sturgeon passage and are known to be severely impeding lake sturgeon recovery (Runstrom and St. Pierre 2004). The Upper Mississippi River has 37 locks and dams on it (USACE 2012). Lake sturgeon migration is disrupted by a series of low-head navigation dams on the mainstem of the upper Mississippi River, and high-head dams on tributaries of upper Mississippi River block historical migrations and isolate groups of sturgeons above and below these dams (Knights et al. 2002). Lock and Dam 19 at Keokuk, Iowa on the upper Mississippi, is a nearly complete barrier to lake sturgeon because of its hydropower function (Wilcox, et al. 2004). Since 2011, 11 hydroelectric projects have been proposed on the upper Mississippi River, at existing Army Corps of Engineers facilities; and 5 new hydropower projects have been proposed to FERC (FERC 2016).

In the Kettle River, Sandstone Dam was built in 1908 at river km 22, and blocks lake sturgeon migration upstream (Borkholder et al. 2002).

In the Namekagon River, Trego Dam was constructed in 1927 at river km 50, and blocks lake sturgeon access to upstream habitat (Kampa et al. 2014a, b).

The lake sturgeon population of Yellow Lake has been isolated from the St. Croix River population since a dam was built on the Danbury Flowage in the 1930s (Wendell and Damman 2011).

A former major sturgeon spawning site at the confluence of the Turtle and Flambeau rivers was destroyed in 1926 by construction of a dam on the Flambeau River that created the Turtle-Flambeau Flowage, a lake impoundment of approximately 14,000 acres (WNRM 2009).

In the Wisconsin River, construction of Lake Wisconsin ended the Fox-Wisconsin Waterway connection to the Mississippi River. There are now 26 dams on the Wisconsin

River, blocking upstream lake sturgeon passage. Knights et al. (2002, p. 520) found that the hydroelectric dam at Prairie du Sac marked the boundary for upstream sturgeon movement in the Wisconsin River, and was partially isolating populations that were historically allowed to mix and previously formed a single population. Construction of fish passage facilities at Prairie du Sac have been delayed because of concerns that invasive fish species would move past the dam into the Wisconsin River and Great Lakes (FERC 2016).

In the Illinois River, 2 hydroelectric projects have been proposed at existing Army Corps of Engineers facilities since 2011 (FERC 2016).

In the Fox River, 2 hydroelectric projects have been proposed at existing Army Corps of Engineers facilities, and 1 new hydropower project has been proposed to FERC (FERC 2016).

In the Baraboo River, placement of dams has blocked lake sturgeon access to historically utilized reaches in the upper portions of the river (WDNR 2013).

Missouri River Sturgeon Are Threatened by Dams and Hydroelectric Facilities

In the Osage River, construction of Bagnell Dam in 1931 impounded lower portions of the river where lake sturgeon were formerly often caught (Pflieger 1997).

Ohio River Sturgeon Are Threatened by Dams and Hydroelectric Facilities

The placement of navigation dams in the Ohio River essentially rendered most of the entire basin's habitat unsuitable for lake sturgeon (Trautman 1981).

In the East Fork White River, the Williams Dam hydropower structure built in 1913 blocks upstream movement of lake sturgeon to more than 1,500 stream miles (INDNR 2013). Williams Dam was mothballed in 1948 but is now being revived for electrical generation (INDNR 2013). A license for a 4 megawatt project at Williams Dam was filed with FERC in 2012 and a 50-year license was issued by FERC in 2014 (FERC 2016). Despite the fact that the East Fork White River has Indiana's only known riverine population of lake sturgeon, the U.S. Fish and Wildlife Service did not exert its authority during the FERC process to push for fish passage at the dam, so dam removal or fish passage were not considered in the FERC process. The dam will be operated as run of the river The only FERC mitigation measures for sturgeon for the new dam consist of "restoring" existing sturgeon habitat immediately downstream of the dam to pre-construction conditions, refraining from conducting in-water construction during the sturgeon spawning period, developing plans for reservoir drawdown and refill, water quality monitoring, and spillway flows, and installing trash racks aimed at preventing sturgeon entrainment (FERC 2016). Federal agencies missed the chance to expand habitat for the only naturally reproducing population of lake sturgeon remaining in the entire Ohio River basin.

Since 2011, 10 hydroelectric projects have been proposed on the Ohio River, at existing Army Corps of Engineers dams, locks and reservoirs, and 2 new hydroelectric projects have been proposed to FERC (FERC 2016). Seven hydroelectric projects have been proposed since 2011 on the Allegheny River, at existing Army Corps of Engineers facilities (FERC 2016).

Arkansas-White River Sturgeon Are Threatened by Dams and Hydroelectric Facilities

Since 2011, 10 hydroelectric projects have been proposed on the Arkansas River, at existing Army Corps of Engineers dams, locks and reservoirs (FERC 2016).

Lower Mississippi River Sturgeon Are Threatened by Dams and Hydroelectric Facilities

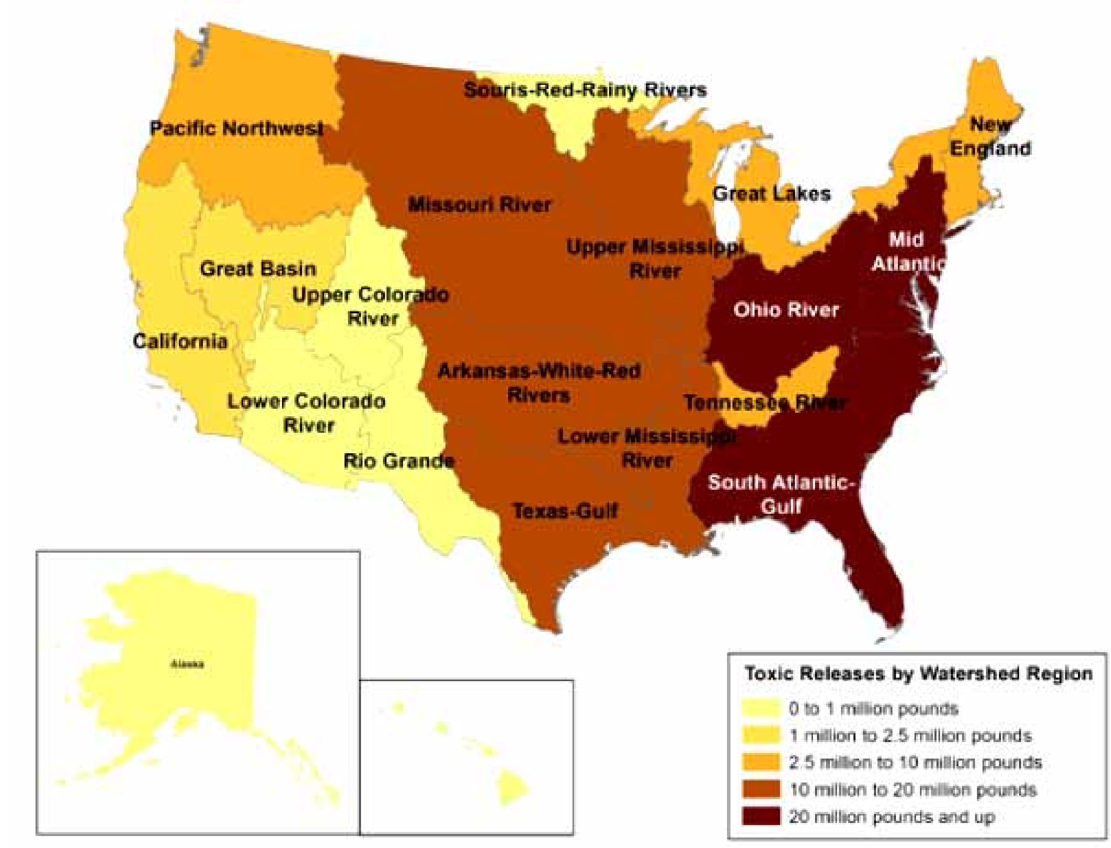
In the Caddo River tributary of the Ouachita River in Arkansas, Lake DeGray Dam was constructed from 1963-1972, just downstream from where a very large (9 feet, 10 inches) lake sturgeon was taken in 1945 (Crump and Robison 2000).

Since 2011, 3 hydroelectric projects have been proposed on the Ouachita River, at existing Army Corps of Engineers dams, locks and reservoirs, and 1 proposal to increase water withdrawal capacity at an existing project was submitted to FERC (FERC 2016).

An emerging threat to lake sturgeon habitat in the lower Mississippi River is the proliferation of hydrokinetic projects. In-stream hydrokinetic energy projects generate electricity from the horizontal flow of water in rivers, waterways and canals, using in-stream turbines that are submerged, floating or tethered to existing structures like bridge abutments or other in-water infrastructure (USFWS 2015). Energy-generating mechanisms may be placed as individual units or in arrays - some are placed downstream from existing hydropower projects. Since 2011, there have been 55 hydrokinetic projects proposed for the Lower Mississippi River, mostly in Louisiana, but also in Arkansas, Tennessee, Mississippi, Kentucky and Missouri (FERC 2016). None of the applications for these hydrokinetic projects mention or address potential impacts to lake sturgeon, however the Department of Interior comments on almost all of the FERC applications raise concerns about adverse effects to fish and wildlife resources and threatened/endangered species, and deleterious changes to water quantity and quality (FERC 2016). The U.S. Fish and Wildlife Service notes multiple concerns with hydrokinetic turbines: they may impact fish behavior, altering migration or other movement; anchoring of underwater structures could impact benthic habitat, including fish foraging habitat; underwater noise and vibration could affect fish; entrainment (being sucked into the turbines) or impingement (pinned against a structure) of fish is possible; large scale projects have the potential to alter in-stream hydraulics, sediment transport and deposition, and other river characteristics, with impacts on habitat quality and quantity both upstream and downstream of the project (USFWS 2015).

Pollution and Contaminants

Freshwater pollution is a rampant problem in the United States despite the existence of the Clean Water Act. The U.S. Environmental Protection Agency concluded that 53 percent of the nation’s rivers and streams and 67 percent of lakes, ponds, and reservoirs assessed remain too polluted for fishing (Inglis et al. 2014, p. 10). Toxic discharges from industrial facilities are responsible for polluting over 17,000 miles of rivers and 210,000 acres of lakes, ponds, and estuaries nationwide (Inglis et al. 2014). In 2012, 206 million pounds of toxic chemicals were dumped into American waterways by industrial facilities (Inglis et al. 2014, p. 4).



Industrial discharges of toxic chemicals by watershed region (from Inglis et al. 2014)

Pollutants and contamination from a variety of sources has been suggested as a cause for decline in lake sturgeon (Harkness and Dymond 1961; Mongeau et al. 1982; Rousseaux et al. 1995; COSEWIC 2006, p. 64). Contaminants enter lake sturgeon waterways through agricultural runoff and industrial pollution. Some of the most polluted watersheds in the country are where lake sturgeon formerly occurred or currently reside.

Juvenile sturgeon are known to be sensitive to chemical pollutants (Peake 1999) and sturgeon eggs and embryos are particularly sensitive to pollutants, with some heavy metals known to be toxic at very minute concentrations (Detlaff et al. 1993). Contaminants that sturgeon acquire through the food chain could interfere with successful reproduction (USFWS 1995), as has been documented with the Kootenai River white sturgeon population (Georgi 1993).

Persistent Bioaccumulative and Toxic Chemicals

Because of their benthic feeding strategy coupled with high body fat and their longevity, lake sturgeon are vulnerable to bioaccumulation of toxic pollutants (USFWS 1995; Beamesderfer and Farr 1997; WDNR 2008, p.4). Bioaccumulation is when a substance occurs at higher concentrations as it moves up a biological food chain. Toxic bioaccumulates such as DDT, PCBs, mercury, dioxins and furans enter waterways from hazard waste sites, paper recycling plants, and other industrial facilities and accumulate in fish tissue at concentrations thousands of times higher than the water. These toxic substances are especially troubling for lake sturgeon because concentrations are highest in sediments at the bottom of a lake or river where sturgeon feed (WDNR 2008, p. 4).

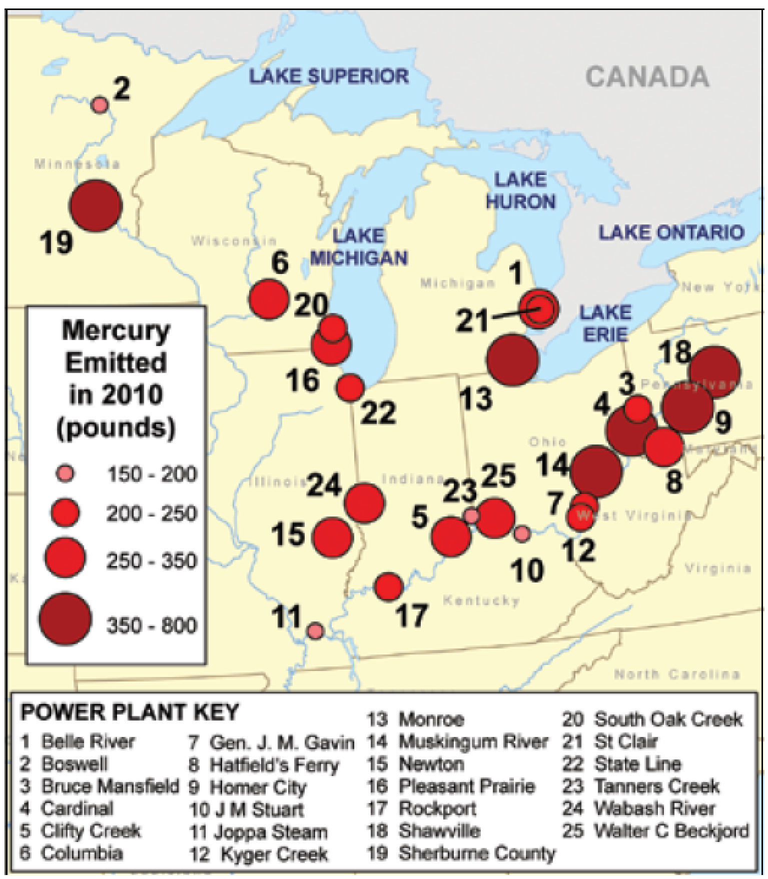
While the presence of persistent bioaccumulative and toxic chemicals has significantly decreased over the last four decades after many of them were banned and polluting industries were regulated, these toxics still remain a problem in the Great Lakes basin. The USEPA has identified 43 areas of concern for water quality in the Great Lakes basin due to a high amount of environmental degradation from pollutants, and persistent bioaccumulative and toxic chemicals are the main water quality issues for many of these areas (CUSCGLWC 2014).

Areas of water quality concern in the Great Lakes (from the Canada-United States Collaboration for Great Lakes Water Quality)

Toxic bioaccumulates are known to produce acute lesions, retard growth and impair reproduction of aquatic life in general (Williamson 2003, p. 33). Although few studies have examined the impacts of persistent bioaccumulative and toxic chemicals specifically on lake sturgeon (Candrl et al. 2012, p. 1), there is information on impacts to other sturgeon species. Deformities and ulcerations thought to be caused by water pollution have been observed in Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) populations in North Carolina (Moser and Ross 1995; Williamson 2003, p. 33). Studies on shortnose sturgeon (*Acipenser brevirostrum*) in South Carolina found that dioxins and furans can adversely affect the development of sturgeon fry (Williamson 2003, p. 33).

Polychlorinated biphenyls (PCBs) are perhaps the most infamous and long-lasting of bioaccumulative toxics (Inglis et al. 2014, p. 10), and they have been linked to the decline of lake sturgeon in several rivers (Wesley and Duffy 1999, p. 47,56; Auer 2003, p. 14; Gunderman and Elliott 2004, p. 32; COSEWIC 2006, p. 64; WDNR 2008, p. 4). Although PCBs were banned in the 1970s, they are still leaching into the environment from old waste sites and contaminated sediments (Candrl et al. 2012, p. 1; Inglis et al. 2014, p. 11). Bioaccumulation of PCBs may reduce sturgeon survival (Emmett et al. 1991). PCB concentrations of 3-7 ppm in other fish species have been shown to increase egg and larvae mortality (Hansen et al. 1974; Hogan and Brauhn 1975; Herbold and Moyle 1989, p. 54).

Sturgeons and other long-lived benthivores are particularly susceptible to increases in mercury concentrations (Headon and Pope 1990), since heavy metals and similar contaminants accumulate in their fatty tissues. Studies on white sturgeon (*Acipenser transmontanus*) have shown that mercury accumulation has a negative effect on their reproduction (Feist et al. 2005; Webb et al. 2006). Juvenile green sturgeon (*Acipenser medirostris*) and white sturgeon that were exposed to dietary methylmercury in lab experiments had significantly higher mortality and lower growth rates (Lee et al. 2011).



Mercury emissions from coal-fired power plants in the Great Lakes states (from Stamper et al. 2012)

When mercury emissions settle onto land and into water, microorganisms convert it into the highly toxic and bioaccumulatory form of methylmercury (Stamper et al. 2012). Dam impoundments increase production of methylmercury and contaminate nearby fish populations and those located downstream, by flooding terrestrial areas and causing decomposition of organic matter (Stokes and Wren 1987; Grondin et al. 1995; Zhong and Power 1996b). Mercury is also deposited into lake sturgeon habitats by coal-fired power plants. Aquatic species in the Great Lakes region are especially at risk since this area is a net sink for mercury, meaning that more mercury gets into the lakes than what comes out of them through re-emission or draining into the ocean (Stamper et al. 2012). There are more than 144 coal-fired power plants in the eight states that surround the Great Lakes, and they emit more than 13,000 pounds of mercury into the air every year (Stamper et al. 2012). Almost all fish that could be caught for consumption in the Great Lakes have dietary advisories due to the high concentrations of mercury in their meat (Stamper et al. 2012, p. 3).

Lake sturgeon in Michigan have shown toxic loading of mercury in the Menominee River and Millecoquin Lake, and lake sturgeon from Green Bay and the Menominee River exceed recommended level for PCBs (Hay-Chmielewski and Whelan 1997, p. 39).

High concentrations of zinc and copper are thought to inhibit reproductive success for white sturgeon (*Acipenser transmontanus*) and jeopardize survival of sturgeon eggs and larvae (Partridge 1983; Apperson 1992).

Lampricides

The sea lamprey (*Petromyzon marinus*) is an invasive species that was accidentally introduced into the Great Lakes in the early 20th century through shipping canals. The species is considered a pest and represents a threat to the Great Lakes and other areas where it is now found as it is a non-native component of the ecosystem and is known to parasitize and feed on large native fish. While sea lampreys can negatively impact local fish populations through predation, chemicals used for lamprey population control can also have damaging effects (Pratt 2009 p. 28).

Lake sturgeon have been shown to be more sensitive to lampricide exposure than rainbow trout, northern pike, or muskellunge (Johnson et al 2010, p. 20), and smaller lake sturgeon are particularly sensitive (Johnson et al. 1999; Boogaard et al. 2003; Williams 2009; Kerr et al 2011). The toxicity of lampricides is affected by the pH of the water so that changes to water bodies that result in decreasing pH, such as any sort of acidity-building contamination, will increase the toxicity of lampricide to lake sturgeon (Johnson et al 2012 p. 20). Sakamoto et al. (2016) demonstrated neurophysiological and behavioral changes, including changes in olfactory capabilities of young-of-the-year lake sturgeon, from the lampricide TFM, commonly used to control sea lamprey in the Great Lakes. At ecologically relevant concentrations of TFM, lake sturgeon had reduced olfactory response to food cues and reduced consumption of food. The commonality of habitats between sturgeon and lamprey ammocoetes suggests that there may be effects at the ecosystem level in streams that undergo lamprey control treatments.

Marsden and Langdon (2012) found that in Lake Champlain, ongoing chemical treatments for sea lamprey control posed risks for lake sturgeon.

Recommended changes to sea lamprey treatment policies (Hay-Chmielewski and Whelan 1997, p. 35), including using concentrations of TFM that are fatal to sea lamprey but not to lake sturgeon, and scheduling treatments to avoid spawning migrations, incubation times, and larval drift period of lake sturgeon, have mostly been implemented and should ensure that chemical treatments will not adversely affect lake sturgeon rehabilitation.

Pulp and Paper Industry

Pollution from the pulp and paper industry has long impacted lake sturgeon populations (Houston 1987, p. 177; Moreau 1994, p. 25; O'Neal 1997, p. 49-50; Williamson 2003, p. 48; Gunderman and Elliott 2004, p. 33; COSEWIC 2006, p. 64). Chemical effluent and wood fiber discharged from pulp and paper mills smothered lake sturgeon eggs and food sources while also poisoning their habitat by releasing toxic sulphite waste (Harkness and Dymond 1961; Mosindy 1987; Moreau 1994, p. 25-26; COSEWIC 2006, p. 64) and dioxins, which are unwanted byproducts of pulp and paper processes that use chlorine (O'Neal 1997, p. 49-50).

Numerous watersheds in the lake sturgeon range were degraded by pollution produced by pulp and paper mills. In the 1950s, nearly all fish in the Lake of Two Mountains in Quebec were killed off due to chronic oxygen depletion that resulted from waste disposal by the pulp and paper industry (Le Sauteur 1967; Mongeau and Masse 1976). A pulp mill on the Oconto River in Wisconsin had an immediate impact on fish populations when it began operation in the 1890s; fish kills occurred periodically through the late 1970s, and by 1975, the Oconto River had become the single largest source of ammonia nitrogen on the Wisconsin side of Lake Michigan (Rost et al. 1989; Gunderman and Elliott 2004, p. 33). Muskegon Lake in Michigan once served as the dumping grounds for pulp and paper mills.

The U.S. and Canada have been working jointly to address legacy effects of industrial waste in the Great Lakes, in 1987 targeting 43 "areas of concern" for future clean up; 26 of these located in the U.S. However, between 1987 and 2010, the EPA was able to clean up and remove only one site from this list. The Great Lakes Restoration Initiative was launched in 2010, allocating $700 million to clean up remaining waste sites. Four more sites have since been cleaned up, but the Trump administration budget slashes funding for core Great Lakes restoration programs, including reducing the Great Lakes Restoration Initiative from $300 million to $30 million.

As of 1996, at least 10 pulp and paper mills that that produce virgin pulp and paper from wood discharged their effluent into the Great Lakes or their tributaries, 4 of them in Canada and 6 in the United State (Commoner et al. 1996). Waterborne and airborne dioxin from the mill bleaching process makes its way into the Great Lakes (Commoner et al. 1996). Paper mills are increasingly replacing some or all of the elemental chlorine used for bleaching with chlorine dioxide, which forms much less dioxin and other chlorinated organic compounds, but despite industry claims still produces environmentally significant amounts of dioxin (Commoner et al. 1996). As of 2000, 14 paper mills in Michigan were working to minimize use of elemental chlorine, and reduce emissions and discharge of mercury, nonylphenol ethoxylates in effluent, and hazardous materials and wastes such as solvents, phosphorus, zinc and aluminum (MPPEC & MDEQ 2000). Paper mills in New York within the Great Lakes watershed currently list Polycyclic Aromatic Compounds, Polychlorinated Biphenyls, mercury and Benzoperylene as emissions (Park 2017).

As discussed above in the section on in pollution and contaminants, toxic bioaccumulates such as mercury and dioxins which enter sturgeon waterways accumulate in fish tissue at concentrations thousands of times higher than the water, and are of particular concern for lake sturgeon because concentrations are highest in sediments at the bottom of lakes or rivers where sturgeon feed (WDNR 2008, p. 4). Studies on shortnose sturgeon (*Acipenser brevirostrum*) in South Carolina found that dioxins can adversely affect the development of sturgeon fry (Williamson 2003, p. 33).

Crude Oil Transport

The recent boom in transport of large volumes of oil by railway has resulted in several catastrophic rail accidents that have spilled hundreds of thousands of gallons of crude oil into our nation's waterways - this poses a significant risk to lake sturgeon rivers and habitats. Federal regulatory agencies have allowed a dangerous increase in oil-train traffic, including puncture-prone tank cars that move millions of gallons of explosive oil, with little to no environmental review and a complete lack of adequate response plans for spilled oil (CBD 2015). Significant numbers of oil trains pass directly over and adjacent to the Mississippi River and its tributaries, the Great Lakes including Lake Superior and Lake Michigan, and many rivers throughout the Midwest.

Rail shipments of oil have rapidly increased in the Midwest, fueled by the oil boom in the North Dakota Bakken fields, with trains transporting roughly 72 percent of the approximately 1 million barrels of Bakken produced per day; most of these oil trains pass through Minnesota into Wisconsin, traveling along the Mississippi River before turning toward East Coast oil refineries (CBD 2015). From 30 to 48 dedicated oil trains per week carry Bakken crude into Wisconsin from Minnesota, traveling along the Lake Michigan coast and the Mississippi River (CBD 2015). Gulf Coast refineries are being targeted for a rapid expansion of crude-by-rail activity to transport the western Canadian heavy crude being extracted from the Alberta tar sands; these heavy tar sands, if spilled in a train derailment, could pollute hundreds of miles of the Mississippi River and other Gulf Coast streams (CBD 2015).

The Line 5 Oil Pipeline in Michigan moves 23 million gallons of synthetic crude oil and natural gas liquids per day along the bottomlands of the Straits of Mackinac, a series of narrow waterways between Michigan's Lower and Upper Peninsulas connecting Lake Michigan and Lake Huron. This aging pipeline, built in 1953, is operated by Enbridge, the company responsible for one of the largest inland oil spills in North American history: during a 2010 Enbridge pipeline rupture, previously known cracks formed into a 6 foot gash which spilled over 840,000 gallons of oil into the Kalamazoo River in 2010 (Schnurr 2017). Enbridge has been responsible for more than 800 oil spills in the United States since 2000 (Schnurr 2017).

The Line 5 Oil Pipeline is missing protective coating in numerous places along the underwater section of pipeline, and for much of the history of the pipeline, sections were not properly supported on the Lake Michigan lakebed, where it is subject to strong currents (NWF 2017). Land-based sections of the Line 5 pipeline have leaked at least 29 times since 1968, spilling over 1 million gallons of oil (NWF 2017). The pipeline has been operating without an adequate spill response plan, as required by the Clean Water Act (NWF 2017). A 2016 University of Michigan study estimated that a "worst-case discharge" from Line 5 would jeopardize more than 1,000 km of Lake Huron-Michigan shoreline and specific islands (Schwab 2016).

A Wisconsin refinery recently proposed to ship heavy Canadian crude oil across the Great Lakes in tanker ships. The Calumet Specialty Products project would have built a crude oil loading dock on Lake Superior that would have filled ships with heavy crude oil from Canada and North Dakota. The Coast Guard said it was not prepared to clean-up a spill of heavy crude in deep lake waters. In 2015 Michigan senators introduced federal legislation to ban shipping crude oil by vessel on the Great Lakes and add the basin to a "high risk" regulatory category with greater safety thresholds for oil pipelines. This legislation was never enacted. The Calumet project was dropped in 2015 after widespread opposition, but fluctuating crude oil prices may spur future proposals for shipping crude oil on the Great Lakes.

Sturgeon and their prey base are susceptible to the toxic and deadly effects of spilled oil. Oil spills could smother critical spawning and nursery habitat for lake sturgeon and affect development and survival of sturgeon eggs. Several life-history characteristics of lake sturgeon (i.e., long lifespan, extended residence in river habitats, benthic predator) predispose the species to long-term and repeated exposure to environmental contamination and potential bioaccumulation of toxicants. Heavy oils that settle on river bottoms are later incorporated into the food web as they are consumed by benthic feeders like sturgeon or the macroinvertebrates they feed on.

Agricultural Contaminants

Contaminants from agriculture are thought to be a threat to lake sturgeon populations (Pratt 2009, p. 28). Contamination and nutrient loading caused by fertilizers associated with agriculture have been shown to have an adverse impact on sturgeon populations (Pflieger 1975; Graham 1981; Mosindy 1987; NatureServe 2004; COSEWIC 2006, p. 65). Fertilizers may disrupt the olfactory feeding behaviors of lake sturgeon (Hay-Chmielewski and Whelan 1997). As land use and development increase and farm equipment industrializes, contamination levels are also expected to rise. Farmers now use 35 times as much fertilizer as they did a half-century ago (COSEWIC 2006), and the management practices of fertilizers, such as autumn application, broadcasting on the surface rather that injecting in the soil, and conservation tillage, have changed in a way that increases contaminant runoff (PNAS 2013, p. 6449). Due to the large amounts of phosphorous and nitrogen present in most fertilizers, this contamination is expected to significantly contribute to the nutrient loading of many water bodies (DFO 1992; COSEWIC 2006, p. 65). Eutrophication, caused by excessive nutrients in water bodies which cause dense growth of plant life and death of animal life from lack of oxygen, is a well-documented problem throughout the lake sturgeon's range, especially in the Great Lakes where severe algal blooms have created vast dead zones (Houston 1987; Heuvel and Edwards 1996; Madenjian et al. 2002; Bronte et al. 2003; COSEWIC 2006; Marsden and Langdon 2011; PNAS 2013).

Domestic livestock production also impacts water chemistry, when manure and waste products from feedlots that are in close proximity to streams and manure that is spread on fields over ice in winter enter waterways and contaminate lake sturgeon habitat with additional phosphorous, nitrogen and even antibiotics (DFO 1992; COSEWIC 2006).

Mining

In Michigan, mining has caused localized water quality and quantity problems in some lake sturgeon drainages, due to excessive inflows of fine sediment and sand, disturbance of substrate and sediment transport, inflows of heavy metals, and water diversions for mine processing (Hay-Chmielewski and Whelan 1997, p. 37).

A century of iron ore and taconite mining in northeastern Minnesota has also contributed to mercury, sulfate, and other pollution concerns in the St. Louis River.

Dredging and Channelization

Originally used to facilitate commercial shipping and improve navigation, dredging and channelization of rivers has resulted in the destruction and alteration of numerous sturgeon habitats (Pratt 2009, p. 28). For example, in the Missouri River watershed federal engineers removed snags, constructed dams and reinforced channels on the river in the 1830s, which altered the hydrologic regime (Hesse et al. 1993, p. 327).

Dredging and channelization not only directly alter and destroy lake sturgeon habitat, they also change the erosion and sedimentation processes of rivers and may lead to the direct mortality of some sturgeon when vessel traffic increases (Runstrom and St. Pierre 2004). Changes caused in erosion and sedimentation processes can greatly affect the viability of lake sturgeon populations, as a lack of available, high-quality habitat has been shown to contribute to limited or failed recruitment in sturgeon (Khoroshko 1972; Parsley et al. 1993; Williot et al. 1997; Paragamian et al. 2001; Jager et al. 2002; Draugherty et al 2008, p. 6). Increased erosion and sedimentation can degrade sturgeon spawning and nursery habitats (Runstrom and St. Pierre 2004) and may smother many benthic organisms, including larval sturgeon (Kerr et al. 2011, p. 11).

Dredgeate material excavated during dredging can cover important sturgeon habitats with sediment (Hatten and Parsley 2009; COSEWIC 2006 p. 65) and may also lead to the direct mortality of different sturgeon life stages, by burying individuals or causing their gills to clog (COSEWIC 2006 p. 65). Kock et al. (2006) showed that increased sediment at a white sturgeon spawning site in the Kootenai River of Idaho resulted in the delayed hatching, reduced size, and reduced survival of young sturgeon. McAdam et al. (2005) demonstrated that sedimentation of critical habitat for white sturgeon in the Nechaka River of British Columbia caused a reduction in sturgeon recruitment.

Dredging and channelization impacts have been particularly severe in the Midwest and the tributaries of Lake Erie, the Prairies, and the Rainy River in northern Ohio (Mosindy 1987), where they have led to increased sedimentation, habitat loss and degradation (NatureServe 2004; COSEWIC 2006, p. 65). Since the late 18th century, portions of the St. Marys River have been dredged and blasted (Kauss 1991), and since 1900 the Detroit River has suffered a similar fate (Manny et al. 2006; Kerr et al. 2011). Dredging and channelization have resulted in the destruction of a great portion of lake sturgeon habitat in both the St. Lawrence River and connecting waterways of the Great Lakes (Edwards et al. 1989; MNR 2009). Dredging destroyed a former lake sturgeon spawning shoal in the Niagara River (Carlson 1995). In the lower St. Lawrence River, where dredging is performed annually to maintain navigation channels, the process has a continual impact on sturgeon populations. Harbor construction at river mouths in the mid-1800s caused declines of lake sturgeon in tributaries to Lake Superior (Auer 2003, p. 3). Significant dredging and straightening of streams occurred in the U.S. portion of the Red River basin from the late 1800s to the 1950s, eliminating thousands of kilometers of tributary streams (Aaland et al. 2005, p. 297).

Hondorp et al. (2017) found that channelization of large rivers for navigation and flood control has altered hydrology and bathymetry, and demonstrated an association between channelization and the path use of migrating lake sturgeon, which could increase vulnerability of fish to ship strikes in commercial navigation channels. Hondorp et al. (2017) quantified and compared lake sturgeon selection for navigation channels versus alternative pathways in two multi-channel rivers differentially affected by channelization, but free of barriers to sturgeon movement. Acoustic telemetry was used to quantify lake sturgeon movements. Under the assumption that lake sturgeon navigate by following primary flow paths, lake sturgeon in the more-channelized lower Detroit River were expected to choose navigation channels over alternative pathways and to exhibit greater selection for navigation channels than conspecifics in the less-channelized lower St. Clair River. Acoustic-tagged lake sturgeon in the more-channelized lower Detroit River indeed selected the higher-flow and deeper navigation channels over alternative migration pathways, whereas in the less-channelized lower St. Clair River, sturgeon primarily used pathways alternative to navigation channels. Lake sturgeon selection for navigation channels as migratory pathways also was significantly higher in the more-channelized lower Detroit River than in the less-channelized lower St. Clair River. Hondorp et al. (2017) speculated that use of navigation channels over alternative pathways would increase the spatial overlap of commercial vessels and migrating lake sturgeon, potentially enhancing their vulnerability to ship strikes.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

The late maturation and longevity of lake sturgeon makes populations highly vulnerable to fishery exploitation (Hay-Chmielewski and Whelan 1997, p.28).

Legacy of Overfishing

Commercial fishing has undoubtedly been the most significant factor in historic lake sturgeon declines (COSEWIC 2006, p. 62). The history of the devastation of lake sturgeon in the Great Lakes is illustrative of the pattern for every lake sturgeon population that has been impacted by exploitation - high initial yield followed by a sudden and permanent decline to low or non-existent levels (Harkness and Dymond 1961; MDNR 1973; Brousseau 1987; Houston 1987, p. 175; NatureServe 2004; Pratt 2009, p. 28).

Lake sturgeon were once one of the most abundant and widely distributed endemic fish species in the Great Lakes (Hay-Chmielewski and Whelan 1997; Auer 1999; Peterson 2007). In the early-1800s they were so abundant they were considered a nuisance species by most commercial fisheries, as they fouled or filled their nets while targeting other species ((Stone and Vincent 1900; Harkness and Dymond 1961; Hay-Chmielewski and Whelan 1997). Historical accounts depict lake sturgeon piled like cordwood to be used as fertilizer or as fuel in steamships, or disposed of on beaches to spoil (Stone and Vincent 1900; Harkness and Dymond 1961; Smith 1968). However by 1860 the commercial value of lake sturgeon was recognized and fisheries began targeting and harvesting them in massive quantities for fertilizer, isinglass, biofuel, smoked sturgeon meat and caviar (Stone and Vincent 1900; Houston 1987, p. 183; Hay-Chmielewski and Whelan 1997; Harkness 1988; Williamson 2003). Before the turn of the 20th century, one fishery in Sandusky, Ohio was bringing in more than one million kg of sturgeon annually from the Great Lakes (Houston 1987, p. 182).

Forty years of largely unregulated harvest in the late 1800s led to rapid collapse of lake sturgeon stocks throughout the Great Lakes (Harkness and Dymond 1961; Baldwin et al. 1979; Hay-Chmielewski and Whelan 1997; Auer 1999; Baker and Borgeson 1999). Lake sturgeon catches in Lake Erie and Lake Huron suffered declines of 80% and 56% respectively, over the course of 10 years (1885-1895). The Lake of the Woods sturgeon fishery experienced a 90% decline over seven years (1893-1900). By 1910 the species was considered commercially insignificant in all of the Great Lakes (Baldwin et al. 1979; Smith 1979; Trautman 1981). This led to heavy regulations in the 1920s followed by the closure of most American commercial fisheries by 1980 (Baldwin et al. 1979; Auer 2003; Peterson et al. 2007). Despite widespread fishing restriction measures, the majority of lake sturgeon populations have still not rebounded in the Great Lakes.

While sturgeon harvesting was at its peak, some scientists recommended investigating lake sturgeon biology in order to develop regulatory mechanisms before populations became overexploited (Houston 1987, p. 183). Unfortunately, lake sturgeon populations experienced such dramatic declines that this information was never fully determined. The high pressure placed on lake sturgeon by commercial fishing was exacerbated by the species' slow-growing, late-maturing, and intermittent spawning characteristics (Houston 1987, p. 183; COSEWIC 2006, p. 62). For example in Lake Ontario, lake sturgeon populations were considered to be in decline as early as the 1840s (Whillans 1979), and from the 1920s on fisheries averaged just 2-3% of 1880s production levels (Harkness and Dymond 1961; Houston 1987, p. 175). Lake sturgeon populations in Lake Superior still have not fully recovered from early declines caused by incidental bycatch by the commercial fishing industry during the mid-1800s, expanded harvest in the early 1900s, and continued harvest through the 1930s (Auer 2003, pp. 3-4).

Ricker (1975) concluded that an annual harvest rate of 5% or more on a lake sturgeon population consisting of 12 to 15 age groups or more may eventually cause a major reduction in total biomass and in relative biomass of older individuals. The effects become more pronounced as the number of age classes in a population increases. One way to judge the impact of fishing is to examine age structure and consider how many opportunities an adult sturgeon would have to spawn. This is particularly critical for sturgeon species, given that strong year classes occur infrequently and adults may only spawn every 3-5 years.

While lake sturgeon declines in the Great Lakes have slowed or stopped with the termination of large commercial fishing operations, none of the sturgeon populations have recovered to historic abundance and some populations have even become extirpated (NatureServe 2004).

Current Commercial Fisheries

Because lake sturgeon are classified as threatened or endangered by many states within the species' historic range, the legal trade in lake sturgeon or their products is more restricted than that of many other North American *Acipenseriformes*. Commercial catch of lake sturgeon is now prohibited in all U.S. waters (Williamson 2003, p. 75).

Legal trade in lake sturgeon flesh and caviar is allowed in Michigan, Minnesota, New York and Ohio, and trade in live lake sturgeon is permitted in all of these states except for Ohio (Bruch 1999; Williamson 2003, p. 170). As of 2000, Michigan reported a likely market for smoked sturgeon and caviar within the state, but had no data on its size;

Minnesota trade in lake sturgeon was believed to have diminished because of lack of viable eggs available from commercial sources (Williamson 2003, pp. 169-170).

Current Recreational Fishing

Michigan, Minnesota and Wisconsin continue to allow limited sport catches of lake sturgeon, and is discussed below starting on page 145 in the section on state protections. Sport fishing is of concern where lake sturgeon populations are small or the limits are not adequately protective.

Commercial harvest of lake sturgeon in Minnesota was closed in the 1930s, but sport harvest continues in Minnesota-Canada border waters (MNDNR 2018). Minnesota has had to continue to tighten restrictions for the Minnesota-Canada border fishery since 2000 in response to increasingly heavy fishing pressure and evidence that catch levels were not compatible with sustainable lake sturgeon populations (Welsh 2004, p. 318). Minnesota continued to allow sport harvest of lake sturgeon in the Assiniboine and Red River basins in northern Minnesota through 2006, where there was no recent evidence of naturally reproducing populations (COSEWIC 2006). Minnesota now requires catch and release for lake sturgeon in the Red River of the North; anglers can still take one lake sturgeon per year in Rainy River, Rainy Lake, and Lake of the Woods (MNDNR 2018).

Kentucky, Michigan, Minnesota and Wisconsin also allow some catch and release of lake sturgeon. There is not good information on the potential impacts to lake sturgeon from catch and release fishing.

Many states (Alabama, Illinois, Indiana, Iowa, Kansas, Missouri, Nebraska and Wisconsin) allow sport harvest of other species of sturgeon, often in waters where lake sturgeon occur. This leads to the potential for angler misidentification and inadvertent harvest of lake sturgeon. This is a known problem; for example, the Illinois Department of Natural Resources acknowledges that lake sturgeon is the most likely Illinois endangered or threatened species of fish to be inadvertently taken by sport fishing (ILDNR 2016, p. 5).

International Trade and Poaching

<u>International Trade</u>

The decline and mismanagement of Caspian Sea sturgeon, which in the past have produced the vast majority of the caviar in international trade, is cause for concern over the potential for increased demand for North American caviar in domestic and international markets (Williamson 2003, p. 2). Should the Caspian Sea sturgeon fishery collapse, the global demand for caviar is far above what North American fisheries and commercial aquaculture operations are currently producing (Williamson 2003, p. 2). The volume of the international caviar trade raises questions about the extent to which North American sturgeon and paddlefish populations might be able to serve as substitutes for Caspian Sea caviar (Williamson 2003, pp. 145-148). An increasing demand for North American sturgeon roe for the caviar trade is concerning because it has been reported that lake sturgeon roe produces the finest caviar of any North American species (Williamson 2003, p. 75). Law enforcement authorities are beginning to detect caviar from North American species mislabeled and sold fraudulently as Caspian Sea product (Williamson 2003, p. 18).

Poaching

Illegal harvest of lake sturgeon potentially poses substantial harm to small populations that concentrate in rivers during spawning (Hay-Chmielewski and Whelan 1997, p.30). Enough financial incentives exist to promote poaching of lake sturgeon. One study by Runstrom and St. Pierre (2004) found that despite the fact that lake sturgeon harvest from the Mississippi River was prohibited, caviar collection was still rampant. COSEWIC (2006, p. 62) estimated that several thousand lake sturgeon are likely sold illegally each year due to the high value of sturgeon roe and meat. There have been accounts of illegal trade of lake sturgeon in the northern reaches of the Mississippi River basin and in the Great Lakes, with known illegal poaching activity in Michigan's St. Clair River, the Black River upstream from Black Lake, and the Sturgeon River in Baraga County, Michigan; and in Minnesota (Williamson 2003, p. 179). Poaching was documented to be a problem on the St. Clair, Detroit, Indian and Black rivers in Michigan (Hay-Chmielewski and Whelan 1997, p.30). Incidental/illegal harvest of lake sturgeon during spawning continues to be a problem in Michigan (MDNR 2015). Poaching of lake sturgeon continues to be a problem on the Manistee River in Michigan (Barber 2016). Increased attention by law enforcement and volunteer 'watch' groups has reduced poaching (Hay-Chmielewski and Whelan 1997, p.30).

Disease and Predation

Lake sturgeon are parasitized by trematodes, nematodes, acanthocephalans, cestodes and coelenterates (Harkness and Dymond 1961; Choudhury and Dick 1993; Choudhury et al. 1996; COSEWIC 2006). Choudhury and Dick (1993) recovered 19 species of parasites from lake sturgeon in major waterways of central Canada. Helminth parasites are closely correlated with the lake sturgeon's diet, and have been known to weaken their host individuals (Choudhury and Dick 1993).

Lake sturgeon populations are negatively impacted by predation from invasive and introduced fish, including parasitic lampreys such as sea lamprey (*Petromyzon marinus*) and silver lamprey (*Ichthyomyzon unicuspis*), round goby (*Neogobius melanostomus*) and common carp (*Cyprius carpio*). Rusty crayfish (*Orconectes rusticus*) also prey on lake sturgeon eggs and are potential predators of larval lake sturgeon. See the discussion on invasive species on page 159 below.

Inadequacy of Existing Regulatory Mechanisms

International Protections

CITES

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international treaty that provides the international legal framework for controls on international trade in threatened and endangered wildlife and wildlife products (Williamson 2003, p. 14). Protection for species at risk is provided under the Convention's Appendices, which describe the status of the species and determine what species may be used in international commercial trade. The most endangered species are listed in Appendix I, which includes all species threatened with extinction that are or may be affected by trade; commercial trade is not permitted for these species, and other trade for purposes such as scientific research is strictly controlled through import and export permits. Appendix II species are those that are not rare or endangered at present but could become so if trade is not regulated; international trade in such species requires the issuance of a CITES export permit by the exporting country. Appendix III species are not endangered but are subject to regulation within the listing nation for the purposes of preventing or restricting exploitation and promoting the cooperation of other parties in the control of trade. Appendix III requires the issuance of an export permit by the listing country, or a Certificate of Origin from all other parties. The lake sturgeon was listed under Appendix II of CITES from 1986 to 1996 as a “vulnerable” species (St. Pierre and Runstrom 2004).

One of the weaknesses of CITES is that any party to the treaty may unilaterally state that it will not abide by the provisions of the Convention relating to trade in a particular species listed in the Appendices, with restrictions on when such a reservation may be entered for Appendix I or II species (Williamson 2003, p. 15). While protection under CITES could help prevent commercial exploitation of lake sturgeon for export, the CITES listing did not address habitat loss and degradation or many of the other threats facing lake sturgeon.

During the period of Appendix II listing, the lake sturgeon was considered a species in which trade must be regulated to avoid overutilization. No legal commercial trade of U.S. lake sturgeon is allowed, so any U.S. commercial trade in the species originated from the Canadian fisheries (Williamson 2003, pp. 155, 167, 169). According to 1978-1984 CITES data, exports of lake sturgeon were restricted to meat exported from Canada to the U.S., with an average 6,416 kg/year exported during this 7-year period (CITES 2000, p.14). For 1998, the most important international trade in wild specimens of lake sturgeon was still represented by meat; exports from Canada to the U.S. totaled 18,170 kg; this volume was the largest quantity of sturgeon meat trade reported in 1998 CITES Annual Reports for all Acipenseriformes (CITES 2000, p.14). A total of 1,120 live specimens (probably juvenile fish) were exported from the U.S. to Taiwan, and 9 specimens from a pre-Convention stock (probably adults to be used as broodstock in captive breeding facilities) were exported from the U.S. to Germany and the Russian Federation (CITES 2000, p.14).

The lake sturgeon was delisted from CITES in 2004 and designated as a species of “least concern” (St. Pierre and Runstrom 2004), so the species is no longer protected under CITES.

COSEWIC and Bi-National Efforts

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC), comprised of Canadian federal, provincial, and territorial governments, as well as nongovernmental representatives, provides a scientifically based evaluation of the national status of Canadian species, subspecies, and separate populations suspected of being at risk. While COSEWIC designations have no legal standing, they are well respected (Williamson 2003, p. 14).

The lake sturgeon is not protected as a federally threatened or endangered species in Canada (Williamson 2003, p. 124). The species is protected and managed in Canada under the *Federal Fisheries Act* in each province of occurrence. Regulations differ between provinces and are revised annually. Throughout its range in Canada, the lake sturgeon commercial, recreational and First Nations fisheries have been subject to special regulation.

There have been attempts to coordinate an overall joint strategy for sturgeon management and conservation in the United States and Canada, through the National Paddlefish and Sturgeon Steering Committee. There are also established inter-jurisdictional and international bodies and agreements covering certain geographic regions and the species that fall within them, such as the Atlantic States Marine Fisheries Commission and Great Lakes Fisheries Commission. However, due to the number of species involved, their varying status and needs, and the sheer number of political and bureaucratic entities involved, it has been difficult to coordinate any centralized management authority or strategy (Williamson 2003, p. 16).

Federal Protections

The lake sturgeon is not currently protected under the federal Endangered Species Act. While several existing federal laws and regulations are aimed at protecting aquatic resources, these laws do not provide sufficient protection for individual imperiled species. Existing federal regulatory mechanisms that could potentially provide protection for the lake sturgeon include consideration under the National Environmental Policy Act or the Clean Water Act, co-occurrence with other aquatic species protected by the Endangered Species Act, and the FERC relicensing process.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires federal agencies to consider the effects of management actions on the environment. NEPA also requires federal agencies to fully and publicly disclose the potential environmental impacts of all proposed projects. Actions taken by federal agencies (such as the Army Corps of Engineers, Department of the Interior, Federal Energy Regulatory Commission, Bureau of Reclamation, and Environmental Protection Agency) with the potential to impact lake sturgeon or lake sturgeon habitat are subject to the NEPA process. The NEPA process requires these agencies to describe a proposed action, consider alternatives, identify and disclose potential environmental impacts of each alternative, and involve the public in the decision-making process. The public can provide input on what issues should be addressed in an Environmental Impact Statement and can comment on the findings in an agency's NEPA documents. Lead agencies are required to take into consideration all public comments received in regard to NEPA documents during the comment period. However, NEPA does not explicitly prohibit federal agencies from choosing alternatives that may negatively affect imperiled species. Even if lake sturgeon or their habitat are present in a federal agency's project area, NEPA does not prohibit these agencies from choosing project alternatives that could negatively affect individual sturgeon, sturgeon populations or potential sturgeon habitat.

Clean Water Act

The Clean Water Act (CWA) exists to establish the basic structure for regulating the discharge of pollutants into U.S. waters, and for regulating quality standards of U.S. surface waters. Under the CWA, the U.S. Environmental Protection Agency (EPA) implements pollution control programs and sets wastewater standards for industry and water quality standards for all contaminants in surface waters. The CWA also provides federal funding to restore habitat, clean up toxic pollutants and reduce run-off from farms and cities.

Implementation of the CWA in the 1970s was credited with improving water quality in many lake sturgeon habitats and increasing lake sturgeon spawning success, for example in Rainy River, Minnesota (Kallock 2008; MNDNR 2014b).

However, by the time the CWA was passed, much of the damage to former lake sturgeon populations had already been done, and while the CWA may regulate pollutant discharge, it does not restrict all potential contaminants. The CWA has little impact on other threats that are preventing lake sturgeon populations from recovering, such as presence of dams and barriers, overfishing, and the impacts of urbanization.

Under Section 404 of the CWA, discharge of pollutants into waters of the U.S. is prohibited absent a permit from the U.S. Army Corps of Engineers. Theoretically the CWA should provide some protection for stream and lake habitats used by lake sturgeon. However, implementation of the CWA, and the Section 404 program in particular, has fallen far short of Congress's intent to protect water quality (e.g., see Morriss et al. 2001). The EPA is also underfunded for addressing widespread pollution problems; and the Trump's administration's proposed EPA budget cuts the agency by 31 percent from $8.2 billion to $5.7 billion, and eliminates a program to protect the Great Lakes.

The CWA does not address the leading cause of pollution today, "nonpoint" source pollution. Many pollution standards for industries are out of date, and new pollutant sources from pesticides and pharmaceuticals are constantly emerging. Also, much of the aging infrastructure for industries which attempted to address pollution during the early years of the CWA is in need of upgrades.

De facto evidence that the Clean Water Act alone cannot protect lake sturgeon and their habitat is that other aquatic species which somewhat overlap with the range and habitat of the lake sturgeon have not been adequately protected by the CWA. For example in the Midwest, many imperiled freshwater mussels have had to be protected under the federal Endangered Species Act as endangered despite decades of CWA protections, such as the northern riffleshell (*Epioblasma torulosa rangiana*) and clubshell (*Pleurobema clava*) listed in 1993, and the rayed bean (*Villosa fabalis*) and snuffbox (*Epioblasma triquetra*) listed in 2012.

<u>Co-Occurrence with Other ESA Species</u>

Lake sturgeon could benefit in some areas from co-occurrence with other freshwater aquatic species already protected under the federal Endangered Species Act. One example is the pallid sturgeon (*Scaphirhynchus albus*), federally listed as endangered. The pallid sturgeon's range overlaps with lake sturgeon in the Mississippi River downstream of its confluence with the Missouri River, the Ohio River below Dam #53, and portions of the Missouri River (USFWS 1990). Populations of shovelnose sturgeon (*Scaphirhynchus platorynchus*) where they overlap with pallid sturgeon in the Missouri and Mississippi River basins are also listed as threatened due to their similarity of appearance and difficulty in differentiating these two sturgeon species in the wild

(USFWS 2010). Conservation plans in the Mississippi River often include provisions for pallid and shovelnose sturgeon, such as increased regulations on water quality, river usage, and dams and water diversions.

Several freshwater mussels that are federally listed as endangered overlap with portions of lake sturgeon habitat. The northern riffleshell (*Epioblasma torulosa rangiana*) overlaps with lake sturgeon only in the upper 2 miles of the Detroit River, Michigan (USFWS 1993). The clubshell (*Pleurobema clava*) does not overlap with any current lake sturgeon populations (USFWS 1993). Both the clubshell and the northern riffleshell have been reintroduced to the upper Tennessee River in northwestern Alabama, where lake sturgeon occur, but these mussel populations are designated as experimental, non-essential populations with minimal formal protections (USFWS 2001). The pink mucket (*Lampsilis orbiculata*) overlaps with lake sturgeon in the Tennessee, Cumberland, Clinch and French Broad rivers in Tennessee; in the lower Ohio River; and in the White River, Arkansas, where there may not be any remaining lake sturgeon (USFWS 1985; Cummings and Cordeiro 2012). Very small numbers of the rayed bean (*Villosa fabalis*) overlap with lake sturgeon in the Black River, Michigan, and the lower St Joseph River in Michigan and Indiana (USFWS 2012). The snuffbox (*Epioblasma triquetra*) overlaps with lake sturgeon in the Tennessee River, Alabama; Grand River, Michigan; Clinch River, Tennessee; Mississippi and St. Croix rivers, Minnesota; and the St. Croix and Wolf rivers, Wisconsin (USFWS 2012). The Higgins pearlymussel (*Lampsilis higginsii*) overlaps with lake sturgeon in the upper Mississippi River basin, the St. Croix River and the Wisconsin River (USFWS 2003).

The overlap of pallid sturgeon and listed freshwater mussels with lake sturgeon habitat represents only a small portion of the known range of lake sturgeon. Despite the fact that these species inhabit some of the same river reaches, protection by proxy can only go so far. For instance, pallid sturgeon are most often associated with sandy and fine bottom substrates while adult lake sturgeon have been found over a wide variety of substrates, including boulders and gravel. Additionally, while pallid sturgeon have been documented near the tips of wing-dikes, utilizing side channels, and in inundated floodplains associated with dam discharges (USFWS 2014a, p. 7), lake sturgeon tend more towards deeper, undeveloped areas (COSEWIC 2006, p. 21). While restoration efforts directed at pallid sturgeon may preserve certain conditions necessary for lake sturgeon, other essential habitats may be largely overlooked by pallid sturgeon conservation plans.

Usually, adult lake sturgeon are found in water with a depth of ten or more meters and generally only venture to shallower water for spawning purposes (COSEWIC 2006, p. 29). Neither the pallid sturgeon nor the listed freshwater mussels account for protection of this deeper habitat. Freshwater mussels also tend to be found in shallow water and often prefer mud, gravel or sand (USFWS 1997). Similarly to the lake sturgeon, freshwater mussel populations are highly susceptible to impacts and habitat loss and degradation from dams and reservoirs, which have historically flooded their habitats. While federal protection for freshwater mussels may help deter some new dam development on rivers, it will not ensure that sufficient lake sturgeon habitat is protected and restored.

Habitat Conservation Plans

There are no Endangered Species Act agreements or plans, such as Habitat Conservation Plans, Safe Harbor Agreements or Candidate Conservation Agreements, in either the Great Lakes-Big Rivers, Southeast or Northeast regions that cover the lake sturgeon as a non-listed species (USFWS 2016a).

FERC Relicensing

The Federal Energy Regulatory Commission (FERC) authorizes the construction, operation and maintenance of non-federal hydropower projects and reconsiders licenses under the Federal Power Act (FPA) every 30 to 50 years. Section 10(j) of the FPA allows the U.S. Fish and Wildlife Service (USFWS) to conduct environmental reviews and to make recommendations during relicensing that have the potential to add conditions and mitigations that can benefit native fish such as lake sturgeon. The major issues addressed in comments by the USFWS during FERC relicensing that relate to lake sturgeon include protecting fish from being entrained into dam turbines or impinged on trash racks, providing upstream and downstream fish passage past dams, providing adequate base flows downstream from projects, reducing impoundment fluctuations, and providing flows in dewatered reaches.

Under the Fish and Wildlife Coordination Act (FWCA), FERC is supposed to give fish and wildlife resources "equal consideration" with hydropower and other purposes of water resource development, and incorporate the recommendations of federal and state fish and wildlife agencies. Measures suggested by USFWS to mitigate for project impacts to fish and wildlife resources and to provide protection and enhancement - or an equivalent level of protection - must be accepted by FERC and incorporated into the license unless FERC determines that the recommendations are inconsistent with the FPA or other applicable law. Section 18 of the FPA gives the Service mandatory conditioning authority to prescribe upstream or downstream fish passage; these prescriptions must be incorporated into the license by FERC.

However, state and federal wildlife agency recommendations for fish passage and protection measures can be rejected by FERC if they make a determination that there is not substantial evidence of need – this has resulted in FERC refusing to require fish passage or deferring fish passage for projects which clearly block lake sturgeon migration.

FERC is the federal arbiter of conflicts between federal and state fishery agencies and hydropower developers, who often resist mitigation and compensation measures because they can be expensive and result in reduced power generation. Historically, FERC has failed to adequately protect anadromous fish during licensing and relicensing; given inadequate consideration to fish and wildlife issues in its licensing decisions; been reluctant to impose license conditions for protection of fish and wildlife; and favored hydroelectric development over conservation of fish and wildlife (Bodi and Erdheim 1986). Bodi and Erdheim (1986) detailed FERC's poor track record in complying with statutory standards for protecting anadromous fish, issuing exemptions for small hydropower projects and preliminary permits, deferring consideration of the effects of projects on fish and need for fishways until after it has approved projects, avoiding comprehensive planning for river basins, and inadequately consulting with fish and wildlife agencies.

FERC relicensing often involves negotiations between the USFWS, dam owners, states, other federal agencies such as the Army Corps of Engineers, and stakeholders, that can take very long – sometimes decades – to complete. Negotiated settlements that balance the needs of fish with other competing uses, such as power generation and recreation, often result in minimal gains for lake sturgeon. Additionally, as discussed below, FERC continues to license and re-license new or continuing hydropower and dam projects on lake sturgeon rivers with minimal or no provisions for lake sturgeon.

The fact that FERC licenses come up for review so infrequently (every 30 to 50 years) means that for most rivers with FERC hydroelectric projects that impact lake sturgeon, there will be no opportunity to address dam impacts through the FERC process in the near future. Very few FERC dams that impact lake sturgeon are coming up for review soon. For example, in New York state, where there are more FERC projects commencing relicensing activities by 2020 than in any other state, only 22% (42 of 190 operating or proposed FERC projects, encompassing over 240 hydroelectric developments) will be reviewed soon (USFWS 2016c). There are 231 active FERC projects (seeking new licenses, renewal of licenses or new dam projects) in the Midwest region and 324 active FERC projects in the Northeast region (FERC 2016). As discussed below by region, there are very few current FERC relicensing projects in rivers with lake sturgeon that could benefit lake sturgeon or their habitat, and there are many proposed new FERC hydropower projects that could add more negative impacts to lake sturgeon populations.

Northwestern Minnesota FERC

There do not appear to be any current FERC relicensing projects that could benefit lake sturgeon in the Red River basin or Rainy Lake/Rainy River in Northwestern Minnesota (FERC 2016).

Lake Superior FERC

Current FERC projects being reviewed for relicensing on rivers with lake sturgeon in the Lake Superior basin include: the St. Louis River Hydroelectric Project; the Saxon Falls Project and Superior Falls Project in the Montreal River; the Bond Falls Hydroelectric Project in the Ontonagon River; and the Sturgeon Hydroelectric Project in the Sturgeon River (FERC 2016). Neither the St. Louis River nor the Montreal River projects involve any benefits to lake sturgeon or their habitat. The Sturgeon River project is a dam decommissioning plan that was approved in 2001. A negotiated settlement in the Ontonagon River project resulted in Victoria Dam and Power Plant operations being changed from a peaking power facility to a run-of-river operation during sturgeon spawning season (Fedora 2007).

Western Lake Michigan FERC

FERC relicensing projects in the Menominee River and the Fox River have benefits for lake sturgeon in western Michigan.

In the Menominee River, there are five hydroelectric dams that are within the historic spawning range for lake sturgeon - several of these dams, including the Menominee Dam and White Rapids Dam, located between Menominee, MI and Marinette, WI, currently block upstream movement of lake sturgeon (USFWS 2016b). State agencies are pursuing fish passage projects for lake sturgeon through the FERC relicensing process (GLRI 2010; Donofrio and Utrup 2013; Kampa et al. 2014a). New 30-year licenses issued by FERC mandated development of upstream and downstream fish passage conceptual plans for the White Rapids and Chalk Hill Hydropower Projects (USFWS 2016b). A Menominee Fish Passage Partnership comprised of state and federal agencies, nonprofit conservation organizations and a private energy company developed conceptual plans for fish passage at these lower two dams on the Menominee River. Completion of fish passage at these two dams would make an additional 32 acres of spawning habitat available to Green Bay lake sturgeon and open up 1,398 acres of juvenile sturgeon habitat (USFWS 2016b). Approval and construction of the fish passage projects are years away and the agencies are still seeking funding for construction of a bypass, fish lift, and other facilities to allow lake sturgeon to move past the dams (USFWS 2016b). The long-term fish passage goal is to provide passage for lake sturgeon at all five hydropower dams on the Menominee River by 2020 (GLRI 2010). As part of relicensing negotiations with FERC for the Grand Rapids Hydro Project on the Menominee River, the Wisconsin Public Service Corporation agreed to a modified flow plan that ended hydro-peaking and changed Grand Rapids Dam to run-of-river to improve lake sturgeon spawning habitat in the tailwater below the powerhouse and in a bypass channel. This project took over 15 years to implement and restored only a single mile of lake sturgeon spawning habitat in the bypass channel (USFWS 2016b).

Water level management within the Wolf River-Lake Winnebago-Fox River drainage basin is a highly regulated process that requires the U.S. Army Corps of Engineers to balance fish needs with user interests such as hydropower generation, pleasure boating, fishing, emergent plant restoration, and flood control. The conflict between these uses and users frequently results in the only lake sturgeon spawning grounds in the Lower Fox River frequently becoming dewatered during the egg incubation and larval development period, reducing survival of incubating eggs and larvae (USFWS 2016b). In the Fox River, a condition of a new FERC license for De Pere Dam was collection of flow data resulting from operational modifications, development of an operational plan to protect lake sturgeon which spawn below the dam, and a sturgeon “protection plan” which specifies a minimum water elevation in the pool above the dam and directs adequate water flow over target spawning habitat from April 15 to June 15 (USFWS 2016b).

Two new hydroelectric projects have been proposed for the Fox River, the Menasha-Neenah Hydroelectric Project and the Menasha-Neenah Water Power Project. These projects were given a preliminary permit in 2012 (FERC 2016).

Eastern Lake Michigan FERC

In eastern tributaries of Lake Michigan with lake sturgeon, some dams have been removed through FERC processes, with several new proposed hydroelectric projects or relicensing efforts are underway that may have negative impacts on lake sturgeon.

In the Boardman River, Traverse City Light and Power decided through a FERC process to modify and remove four dams. The Brown Bridge Dam removal was completed in 2013; removal of Boardman Dam and Sabin Dam and modification of Union Street Dam is currently planned for 2018 (USFWS 2016b).

On the St. Joseph River, relicensing is being sought for the Sturgis Dam Hydroelectric Project (major) and a license was issued in 2005 for the Three Rivers Hydroelectric Project (FERC 2016).

On the Kalamazoo River, an environmental assessment was prepared in 2009 under the FERC process for the proposed relicensing of the Calkins Bridge Hydroelectric Project. Lake sturgeon spawning occurs in the Kalamazoo River downstream of the project, with low levels of success and the dam blocks sturgeon access to historical spawning habitat in the Kalamazoo River upstream of the project. Although the Michigan DNR recommended provisions for future fish passage, the USFWS did not reserve its authority under Section 18 of the FPA to prescribe fishways at the project. The only recommended provisions for lake sturgeon were adding cobble substrate to 750 linear feet of the river downstream of the dam to enhance spawning habitat (FERC 2016). In 2013, FERC issued a preliminary permit for a new 13-foot high hydroelectric dam on the Kalamazoo River, the Ceresco Hydroelectric Project (FERC 2016). In 2005 FERC issued a relicense for the existing City of Marshall Hydroelectric Project on the Kalamazoo River. The Michigan DNR had requested provisions for downstream fish passage and fish protection measures to reduce entrainment of fish (it is unclear whether this included sturgeon), which FERC rejected due to insufficient evidence of need; in 2004, the USFWS reserved its authority to prescribe fishways for the project (FERC 2016).

New York FERC

Much of the current and near-term activity regarding FERC relicensing that could have an impact on lake sturgeon is in New York. There are over 190 operating or proposed FERC projects in New York, encompassing over 240 hydroelectric developments (USFWS 2016c). From 2015 through 2020, 47 projects encompassing 62 hydroelectric developments (located on 29 different rivers in 9 watersheds) will commence relicensing activities, more than any other state in the U.S (USFWS 2016c). FERC relicensing of projects in the Oswegatchie, Grasse, St. Regis, St. Lawrence, Raquette and Oswego rivers could benefit lake sturgeon. Some of the specific New York FERC relicensing projects likely to benefit lake sturgeon include:

In the Oswegatchie River, 3 FERC projects encompassing 8 developments received new 40-year licenses in 2012. Settlements were reached with Brookfield Renewable Power (6-development Oswegatchie River Project), Hampshire Paper (Emeryville), and Dunn Paper (Natural Dam) to incorporate fish protection from fish entrainment and downstream and upstream fish passage for lake sturgeon at each site, wherever they are feasible. A fishway is being completed at the Eel Weir development by Brookfield, with a similar fish passage facility to be constructed at Heuvelton in 2017. Base flows have been negotiated, all bypassed reaches are receiving adequate flows, and impoundment fluctuations have been reduced. When implemented, these passage facilities will open up about 60 miles of the Oswegatchie River and allow lake sturgeon to move between currently isolated river reaches (Patch 2011). Despite these improvements, lake sturgeon from the St. Lawrence River will still be blocked from entering the Oswegatchie River by a dam at Ogdensburg. This hydroelectric facility was licensed in 1987, so will not be relicensed until 2027, although the U.S. Fish and Wildlife Service and NYSDEC are exploring the possibility of reopening the license to require fish passage.

In the Grasse River, a new dam proposal in Massena was recently withdrawn. This project would also have served as an ice control structure to facilitate PCB remediation. The dam would have been the first lake sturgeon migration blockage on the Grasse River, which is currently open for about 35 miles to Madrid. The project would have restricted migration of sturgeon and flooded spawning areas. With the project being withdrawn, the river should remain open for the foreseeable future.

In the St. Regis River, another hydroelectric project owned by Brookfield Power at Hogansburg near the mouth of the river underwent relicensing. The license expired in 2015. This was a very small project in disrepair producing very little power. A settlement agreement resulted in Brookfield surrendering its license and agreeing to decommissioning and dam removal (USFWS 2016c). Under the agreement, the St. Regis Mohawk Tribe became a co-licensee with Brookfield and would remove the dam with funding provided by Brookfield (USFWS 2016c). The dam was removed in 2016, reestablishing the St Regis River's connection with the St. Lawrence River.

In the St. Lawrence River, the St. Lawrence-FDR Power Project is the second largest FERC project in New York relicensed to date (912 MW). Major issues were water level fluctuations, fish entrainment, and lost spawning habitat for lake sturgeon during the original project construction in the 1950s. The U.S. Fish and Wildlife Service recommended some habitat improvement mitigations for lake sturgeon (USFWS 2016c).

In the Raquette River, a settlement agreement was reached in 1998 and new licenses were issued in 2002 for 4 projects encompassing 13 powerhouses and a water supply reservoir (158 MW). Year-round flows have been restored to more than 10 miles of previously dewatered reaches, water level fluctuations have been greatly reduced, and 12 of the 13 dams now have downstream fish movement structures and protection from fish entrainment (USFWS 2016c).

In the Oswego River, a settlement was reached for 5 relatively small projects (~25 MW) that provides fish protection and downstream passage at all sites, as well as base flows, flows in three bypassed reaches, and reduced impoundment fluctuations (USFWS 2016c).

Lake Champlain FERC

In the Missisquoi River, Swanton Dam restricts sturgeon migration to the lower 8 miles of the river. However, the dam is not currently used for electric generation, so there is no FERC nexus. There are five additional dams on the Missisquoi River and its tributaries above the Swanton Dam that are currently used to generate hydroelectric power. The Swanton and other dams prevent the recruitment of gravels and cobble to spawning sites (VDFW 2016). The two dams immediately upstream from Swanton, Highgate Falls and Sheldon Springs, have at times altered river flows during the sturgeon spawning period, resulting in unnatural flow patterns that can impact sturgeon spawning success (VDFW 2016). In 1999, Sheldon Vermont Hydro Company entered into a voluntary agreement to operate its Sheldon Springs hydropower project in a run-of-river mode during April and May to improve habitat conditions for spawning lake sturgeon in reaches of the Missisquoi River downstream of Highgate Falls. In 1999, the Vermont Agency of Natural Resources submitted a letter to the Village of Swanton, owner of the project, to request that it extend the run-of-river period through June 15 to further protect lake sturgeon egg incubation and fry emergence; this request was denied, as was a similar request made in 2006 (VDFW 2016). Daily peaking at any hydropower facility in the watershed often cascades through downstream facilities and can impact spawning success; hydropeaking has been documented with daily flow fluctuations well in excess of 1,000 cfs (VDFW 2016).

In the Lamoille River, upstream sturgeon migration is blocked by Peterson Dam. Eight dams have been built on the main stem of the Lamoille River and 7 are used for hydroelectric generation. Spawning success for lake sturgeon can be negatively affected by peaking operations at these dams during the spawning season, which can extend into early June (VDFW 2016).

In the Winooski River, lake sturgeon spawning migration was limited to the lower 9 miles of river by the Winooski Falls even before the existing dam was built on the falls (VDFW 2016). There is no estimate of available spawning habitat in the river today but the dam built at the falls may not have reduced the quantity of spawning or nursery habitat available in the Winooski River (VDFW 2016). There are 15 hydroelectric dams operating in the watershed, some of which can impact sturgeon spawning success by altering the natural flow regime during the spring spawning season (VDFW 2016).

In Otter Creek, lake sturgeon spawning migration was limited to the lower 7.5 miles of the river by the falls in Vergennes. A hydroelectric dam was constructed at these falls; while the dam may not be an obstruction to migration, Otter Creek was dredged from the falls to Lake Champlain to create a channel 8 feet deep and 100 feet wide (VDFW 2016). This dredging project, which was completed in 1900, likely removed most of the suitable spawning substrate for lake sturgeon from the river (VDFW 2016). The dam at the falls prevents recruitment of suitable spawning substrate to the base of the falls (VDFW 2016). Flow regulation in the watershed could also impact the success of sturgeon spawning (VDFW 2016).

Upper Mississippi River FERC

In the Upper Mississippi River, 11 hydropower projects were proposed to FERC since 2011 for which the USFWS formally commented expressing concerns about impacts to fish; despite this, FERC issued preliminary applications for all 11 of these projects without any discussion or evaluation of impacts to lake sturgeon (FERC 2016).

In the Wisconsin River, there are now 26 dams blocking upstream sturgeon passage. A FERC relicensing process for the Prairie du Sac Hydroelectric Dam in the Wisconsin River resulted in installation in 2009 of fish protection structures to minimize fish entrainment and mortality (USFWS 2016b), and will provide future fish passage for lake sturgeon past the dam (Kampa et al. 2014a). There are several recent applications for relicense (Grandmother Falls Hydroelectric Project and Mosinee Hydroelectric Project) and new licenses for dams on the Wisconsin River, including Rhinelander Hydroelectric Project, Stevens Point Hydroelectric Project, Biron Hydroelectric Project, and a major new license issued for the Alexander Hydroelectric Project in 2005 (FERC 2016).

In the Yellow River, a relicense for the Danbury Hydroelectric Project on the Yellow River was issued in 2006 (FERC 2016).

In the Chippewa River, a relicense for the Winter Hydroelectric Project on the East Fork Chippewa River was issued in 2005 (FERC 2016).

In the Flambeau River, a license for the Flambeau Hydroelectric Project was issued in 2004 (FERC 2016).

In the Des Moines River, pending FERC projects include the Ottumwa Hydroelectric Project (an environmental assessment was done in 2007), and a preliminary permit was given for the Saylorville Dam Water Power Project in 2013 (FERC 2016). Despite Iowa DNR formal comments requesting fish studies for the Saylorville Dam project, FERC issued a preliminary permit without requiring any fish studies and with no discussion of potential impacts to lake sturgeon (FERC 2016).

In the Maquoketa River, an application was submitted in 2012 for the Delhi Milldam Water Power Project at the existing Delhi Dam on the South Fork Maquoketa River (FERC 2016); there was no discussion of impacts to lake sturgeon.

In the Illinois River, preliminary permits were recently issued for the La Grange Hydroelectric Water Power at the existing La Grange Dam, and for the Peoria Dam Project (FERC 2016).

Missouri River FERC

The Osage River has 2 reservoirs and 3 dams; Lock and Dam #1 has been non-functional since 1951 but could still be a barrier to lake sturgeon migration; Bagnell Dam forms Lake of the Ozarks and this dam and hydroelectric facility altered flow regimes in the Osage River far downstream from the dam and caused fish mortality at the dam (USFWS 2016b). Flows in the lower Osage River are extremely variable because of hydroelectric peak power generation from Bagnell Dam, some 80 miles upstream. It is likely that at least seasonally, or more frequently at certain flows, the dam is a barrier to fish, including lake sturgeon (USFWS 2016b). In 2007 FERC amended the dam license and required improved stream flows and increased minimum flow in the 80 miles of the lower Osage River (USFWS 2016b). Fish protection will also be improved, including the addition of a barrier net that reduces or prevents fish mortality due to turbine or dam operation (USFWS 2016b).

In the Platte River, a preliminary permit was recently issued for the Chatfield Lake Hydroelectric Project (FERC 2016).

In the Kansas River, a license was issued in 2010 for the Bowersock Mills and Power Company (FERC 2016).

Ohio River FERC

For 2 hydropower projects proposed to FERC since 2011 in the Ohio River, the USFWS formally commented expressing concerns about impacts to fish (Olmsted Lock & Dam Project and Dashields Lock and Dam Project); despite this, FERC issued preliminary applications for these projects without any discussion or evaluation of impacts to lake sturgeon (FERC 2016).

Arkansas-White River FERC

Of the 10 hydropower projects proposed to FERC since 2011 in the Arkansas River, the USFWS formally commented expressing concerns about impacts to fish for 5 of the projects; despite this, FERC issued preliminary applications for these 5 projects without any discussion or evaluation of impacts to lake sturgeon (FERC 2016).

Lower Mississippi River FERC

In the lower Mississippi River there have been 55 in-stream hydrokinetic energy projects proposed to FERC since 2011 (FERC 2016). Despite USFWS concerns and comments to FERC on potential impacts to fish behavior, migration, benthic habitat, foraging habitat, entrainment or impingement, alteration of in-stream hydraulics, sediment transport, and habitat quality (USFWS 2015; FERC 2016), none of the applications for these hydrokinetic projects mention or address potential impacts to lake sturgeon (FERC 2016).

Tribal Protections

In the Great Lakes, several sovereign tribes have jurisdiction over and manage lake sturgeon waters. Tribal management of lake sturgeon primarily occurs in Minnesota, Michigan and Wisconsin (Welsh 2004, p. 323). Restrictions on harvest in these tribal areas vary and can often differ from the regulations of the corresponding state. State regulations regarding the conservation of endangered species can only usurp tribes' rights to hunting and fishing if certain criteria are satisfied (District of Oregon 1988).

Coordination of management strategies and policies between states and tribes, though voluntary, can be highly productive. An example of successful coordination is between the state of Wisconsin, the Menominee Tribe, and the federal government. This coordination resulted in the re-establishment of lake sturgeon on reservation lands through stocking and translocation of nearby lake sturgeon (Runstrom et al. 2002). By bringing together the different parties, lake sturgeon were able to spawn again on reservation lands for the first time in 50 years.

Tribes that are managing and conducting restoration projects for lake sturgeon include: Bay Mills Indian Community, Grand Traverse Band of Ottawa and Chippewa Indians, Gun Lake Tribe, Little River Band of Ottawa Indians, Little Traverse Bay Bands of Odawa Indians, and Sault Ste. Marie Tribe of Chippewa Indians in Michigan; Fond du Lac Band of Lake Superior Chippewa, and White Earth Nation in Minnesota; Mohawk Council of Akwesasne, and St. Regis Mohawk Tribe in New York; Bad River Tribe, Great Lakes Indian Fish and Wildlife Commission, Menominee Indian Tribe of Wisconsin, and Red Cliff Band of Lake Superior Chippewa in Wisconsin; and Rainy River First Nations on the Red River.

Were the lake sturgeon to be federally listed under the Endangered Species Act, coordination between the tribes and the federal government would be required and not voluntary. A secretarial order released in 1997 entitled "American Indian Tribal Rights, Federal–Tribal Trust Responsibilities, and the Endangered Species Act" requires consultations between the federal government and tribal governments regarding the management of tribal trust resources outside tribal territories. This order was designed to integrate the rights of tribes and the implementation of the Endangered Species Act

(Wilkinson 1997). Given the significant restoration efforts and proactive management of lake sturgeon by many tribes, tribal management of lake sturgeon should continue if lake sturgeon are listed under the Endangered Species Act.

After Endangered Species Act listing, federal funding could be made available to tribes for research and management through the Tribal Landowner Incentive Program and the Tribal Wildlife Grant Program. For example, the latter awarded over $250,000 in 2004 to several Great Lakes tribes for lake sturgeon research and rehabilitation (USFWS 2004).

State Protections

State mechanisms that could potentially provide protection for lake sturgeon include: listing as a state endangered or threatened species; state harvest regulations which protect sufficient stocks of mature lake sturgeon of breeding age; artificial propagation and reintroduction of lake sturgeon to former habitats; and dam removal, ecosystem restoration, and habitat enhancement projects in rivers and lakes formerly or currently used by lake sturgeon.

Relying upon state-level protections for the lake sturgeon could lead to numerous inconsistencies since different states list the species at different levels of protection and designate differing harvest regulations and conservation strategies. These inconsistencies are particularly problematic with migratory species such as the lake sturgeon since they utilize different habitats throughout their life and may utilize areas under distinct jurisdictions. Sport fishing is allowed for lake sturgeon in many of the state boundary water areas that sturgeon inhabit, meaning that migrating sturgeon from smaller, less secure populations traveling through boundary waters are vulnerable to harvest.

Many of the states where the lake sturgeon is listed and endangered or threatened offer little or no definition of take. In most cases, significant habitat modification or degradation is not recognized as a form of take (Welsh 2004; p. 325) and habitat condition is rarely a factor in state listing decisions. Not every state in the lake sturgeon's range has a reintroduction program in place nor do all states conduct outreach for lake sturgeon conservation.

State-level regulations for lake sturgeon populations are listed below, in alphabetic order according to state.

<u>State Listings and Fishing Regulations</u>

Alabama

Though original runs of lake sturgeon have been extirpated from Alabama, the state lists the species as "protected" (ADCNR 2015b). Under Alabama state law, as a non-game species lake sturgeon cannot be legally killed, taken, captured, possessed, sold or traded without a scientific collection permit or written permit from the Alabama Department of Conservation and Natural Resources (ADCNR 2018). In 2012 Alabama held its second annual nongame symposium and designated lake sturgeon as "Extirpated/Priority 1" - a species of the highest conservation priority. In 2015 ADCNR updated its Wildlife Action Plan (ADCNR 2015b), listing the lake sturgeon as state protected but considered extirpated. The 2015 Wildlife Action Plan did not specify any conservation actions for lake sturgeon.

Arkansas

Though largely believed to be extirpated, the lake sturgeon is listed as a “species of special concern” by Arkansas (AGFC 2013). This listing does not provide protection or regulatory status. Arkansas approved a Wildlife Action Plan in 2007 to monitor, research and protect the needs of wildlife not addressed by funding available for game species or endangered species (Anderson 2006). The plan identifies the “species of greatest conservation need” for Arkansas, which includes lake sturgeon. The list prioritizes Arkansas species by conservation concern and priority actions for funding and implementation – but the lake sturgeon received a ranking of 30 out of 100, and there are 132 other Arkansas wildlife species ranked of higher conservation concern in the plan. The White River, a significant lake sturgeon habitat, was also given a low ranking for conservation priority in the plan.

Arkansas fishing regulations do not expressly prohibit fishing for or take of lake sturgeon (AGFC 2016, 2018), but a permit is required for collection or handling of any species of special concern, including lake sturgeon. Shovelnose sturgeon over 21” are eligible for sport harvest in Arkansas (except in the Mississippi River between the levees, where they are catch-and-release), including in the White River (AGFC 2016, 2018), leading to the potential for angler misidentification and inadvertent harvest of lake sturgeon.

Georgia

Although original stocks of lake sturgeon have been extirpated from Georgia, the species was thought to be listed as a “species of concern” in the state (Williamson 2003, pp. 17-18), however the Georgia Department of Natural Resources does not provide any information on the protected status of the lake sturgeon other than to mention that it is a primary conservation focus (GADNR 2014, p. 178-179),

No sturgeon species may be taken in freshwater or saltwater in Georgia, and fishing for lake sturgeon is specifically prohibited in the Coosa River and its tributaries; any sturgeon caught accidentally must be released unharmed as soon as possible after capture (GDNR 2015, 2018).

Illinois

The lake sturgeon was first given threatened status in 1981 and since 1994 has been listed as a state endangered species in Illinois (Nyboer et al. 2006; IESPB 2015). “Take” of lake sturgeon for any purpose is prohibited, but it is unclear from Illinois statute or regulations whether habitat modification is defined as take (Welsh 2004, p. 320). The Illinois Department of Natural Resources can issue permits for possession, purchase, or disposition of an endangered species for scientific, educational, zoological/botanical or hobbyist purposes (IDNR 2014). The lake sturgeon is identified as a critical species in the state’s 2012 wildlife action plan (ILDNR 2012).

Illinois allows commercial fishing of shovelnose sturgeon with no size or take limit (ILDNR 2018), which is cause for concern over potential bycatch of lake sturgeon. The Illinois Department of Natural Resources acknowledges that lake sturgeon is the most likely Illinois endangered or threatened species of fish to be taken by sport fishing (ILDNR 2016, p. 5: ILDNR 2018, p. 6); accidental sport catches of lake sturgeon are supposed to be released immediately.

Indiana

The lake sturgeon is listed as a state endangered species in Indiana; it is illegal to take or possess the species (Welsh 2004, p. 320; INDNR 2016, 2018). Indiana defines take as “harassing, hunting, capturing, or killing, or attempting to do those actions.” As of 2004, a state management plan had not been developed for lake sturgeon in Indiana (Welsh 2004, p. 320).

The Indiana Department of Natural Resources implemented new hook restrictions in 2016 on the East Fork of the White River near Williams Dam to protect the last remaining spawning lake sturgeon population and attempt to reduce snagging of adult lake sturgeon by anglers. Of continued concern is that shovelnose sturgeon are eligible for sport harvest in Indiana with a 25” minimum size and no daily bag limit (INDNR 2016, 2018), creating the potential for angler misidentification and inadvertent harvest of lake sturgeon.

Iowa

The lake sturgeon is a state listed endangered species in Iowa (IADNR 2015), and no take, possession, transport, import, export, processing, sale or shipment of endangered species is allowed (IADNR 2018). Lake sturgeon are viewed as critically imperiled according to the Iowa Wildlife Action Plan (IADNR 2012).

There is no open season for lake sturgeon in Iowa, precluding any commercial or sport fishing (IADNR 2014). Pallid sturgeon are also protected in Iowa as an endangered species, and both lake and pallid sturgeon are supposed to be released immediately if caught. However, harvest of shovelnose sturgeon is allowed in all Iowa waters except the Big Sioux River, with a 10-fish daily bag limit; except for the Missouri River where there is 20-fish possession limit (IADNR 2016, 2018), creating the potential for angler misidentification and inadvertent harvest of lake sturgeon.

Kansas

The lake sturgeon was petitioned for endangered status within the state of Kansas in 2009, but the Kansas Department of Wildlife, Parks, and Tourism declined to list the species, instead designating it as a “species in need of conservation” (KDWPT 2009). The KDWPT 2018 fishing regulations (KDWPT 2018a) claim that the lake sturgeon is “considered endangered in Kansas” but that is not the case; the KDWPT list of Kansas Threatened and Endangered Species Statewide does not list it as either threatened or endangered (KDWPT 2018b).

Regardless, no fishing or take is allowed for lake sturgeon; incidentally caught lake sturgeon are not considered unlawfully taken if immediately released (KDWPT 2015).

Kansas allows sport fishing for shovelnose sturgeon but not for pallid sturgeon, which are listed as endangered in Kansas; the fishing regulations summary by the Kansas

Department of Wildlife, Parks, and Tourism includes descriptions to help anglers distinguish between sturgeon species (KDWPT 2016, 2018a).

Kentucky

Although the lake sturgeon is considered “critically imperiled” in Kentucky (KDFWR 2014) and the Kentucky State Nature Preserves Commission (KSNPC 2010) recognizes the species is endangered, it has no formal designation as a protected species in Kentucky (Williamson 2003; Welsh 2004).

Since the beginning of the state’s lake sturgeon reintroduction program in 2007, the Kentucky Department of Fish and Wildlife Resources received numerous reports of anglers catching and retaining lake sturgeon (KDFWR 2014). To prevent lake sturgeon harvest, the KDFWR enacted a regulation (301 KAR 1:201) that makes it illegal to keep any lake sturgeon caught while recreationally fishing; however the Kentucky fishing regulations still allow catch and release of lake sturgeon, including in Lake Cumberland (KDFWR 2016, 2018). Public outreach and information on monitoring and enforcement seem to be lacking and there is no information on potential impacts to lake sturgeon from catch and release.

Michigan

The lake sturgeon is listed as a threatened species in the state of Michigan (Welsh 2004, p. 320). However, Michigan threatened species do not receive the same protection as state-listed endangered species. While take of endangered species is prohibited, take of threatened species is allowed if the Michigan Department of Natural Resources believes that controlled harvest will not detrimentally affect the abundance of the species.

As discussed above, there are many examples throughout history of legal harvest of lake sturgeon at levels previously thought to be adequately protective that have later been shown to be unsustainable. In Michigan itself for example, prior to 1999 most of the state was open to sport catch of lake sturgeon with a minimum size limit of 50 inches and an annual catch of one fish per angler; in 1999 Michigan significantly changed the sport fishing regulations to reduce mortality of lake sturgeon and allow for an increased rate of population recovery (Williamson 2003, pp. 129-130). Michigan subsequently restricted sport fishing of lake sturgeon to only five areas (Williamson 2003, pp. 129-130). The Great Lakes Lake Sturgeon Coordination Meeting cautioned in 2002 that where sturgeon reintroduction efforts are occurring in Michigan, further harvest regulations will likely be needed (Welsh 2004, p. 320).

Michigan has developed a lake sturgeon rehabilitation strategy (Hay-Chmielewski and Whelan 1997) that outlines research needs, evaluates present and potential habitat, establishes population goals, and presents management recommendations. The MDNR has set recovery objectives for Black Lake: develop a population of 1,600 to 2,000 adult lake sturgeon by 2030; achieve a natural recruitment level to sustain this population level; support a fishery with a maximum exploitation rate appropriate for the classification status as defined in the Rehabilitation Strategy; and determine habitat limitations of the Upper Black River and Black Lake by 2025 (MDNR 2016).

Michigan updated its Wildlife Action Plan in 2015 (MDNR 2015). Under the plan, restoration of lake sturgeon is a priority in the state’s large rivers, and has a goal to maintain self-sustaining lake sturgeon populations that allow for a recreational fishery throughout the St. Clair–Detroit River system. Conservation actions in the plan include: implementing Michigan's Lake Sturgeon Rehabilitation Strategy (Hay-Chmielewski and Whelan 1997; Hayes and Caroffino 2012); installing spawning reefs for lake sturgeon in the Kalamazoo River and St. Clair–Detroit River system; policing known spawning areas and continuing and expanding the lake sturgeon guarding program to protect spawning adults from poaching; and using modified sea lamprey abatement treatment protocols where documented natural reproduction of lake sturgeon occurs (MDNR 2015).

Michigan currently allows harvest of 1 lake sturgeon per year per angler where harvest is allowed, which includes: Lake St. Clair and the St. Clair River; Otsego Lake; Black Lake; and all Michigan-Wisconsin boundary waters (MDNR 2017).[1] For the Menominee River (from Grand Rapids Dam downstream to the end of the breakwalls in Green Bay) there is no lake sturgeon harvest allowed, catch-and-release sturgeon fishing only. Michigan allows catch-and-release fishing of lake sturgeon on all other Great Lakes and connecting waters (except Lake St. Clair and the St. Clair River) and all inland waters from July 16 through November 30 (MDNR 2017). Spearing for lake sturgeon is prohibited, except in Black Lake during the limited winter season (MDNR 2017).

Most of the lake sturgeon populations that can be legally fished for sport harvest in Michigan seem to have relatively stable populations. The population estimates for lake sturgeon in the entire St. Clair basin are between 15,000-40,000 fish of all ages (COSEWIC 2006; Pratt 2008; USEPA 2009) or 15,882 adults (Hayes and Caroffino 2012). The Menominee River sturgeon population is estimated to contain 5,272 adults in three river segments that are separated by dams, and thought to be stable (Hayes and Caroffino 2012). The Black Lake population was nearly extirpated (down to 60 spawners by 2000) by legal and illegal harvest but has been rebuilt as a result of harvest regulations implemented in 2000, a streamside hatchery, and intensive stocking efforts (Chalupnicki et al. 2011); the Black Lake population is now considered stable with an estimate of 1,125 adult fish (Hayes and Caroffino 2012). The put-and-take lake sturgeon fishery in Otsego Lake was created through stocking experiments to provide sturgeon fishing opportunities regardless of the lake's sturgeon population size; the current estimate is a small, stable population of 100 adults (Hayes and Caroffino 2012).

There is no information on potential impacts to lake sturgeon from catch and release fishing in other waters of Michigan.

Minnesota

The lake sturgeon is designated as "species of concern" in Minnesota (MNDNR 2018), which does not provide any formal or substantive protections.

The commercial harvest of lake sturgeon in Minnesota was closed in the 1930s. In Minnesota, sport anglers can harvest one lake sturgeon 45-50" or over 75" per year from Minnesota-Canada border waters; the harvest season is open April 24-May 7 and July 1-

[1] Lake St. Clair and St. Clair River harvest season is July 16 through September 30, with a size limit of 42-50 inches; catch and release season is October 1 through November 30. Ostego Lake harvest season is July 16 through March 15, with a size limit of 50 inches minimum. Black Lake Harvest season (spearing and hook-and-line) runs during specific hours the first Saturday in February through the following Wednesday, or until the harvest quota has been reached; there is no size limit. Boundary Waters harvest season is the first Saturday in September through September 30, with a 60" minimum size.

September 30 (MNDNR 2018). Minnesota allows unlimited catch-and-release of lake sturgeon in Canada-Minnesota border waters from October 1 to April 23 and May 8 to 15; and in the Red River year round except from April 15 to June 15 (MNDNR 2018). Minnesota also allows unlimited catch-and-release of lake and shovelnose sturgeon in inland waters (including in Lake Superior and the St. Louis River), with the catch-and-release season only closed from April 15 to June 15 (MNDNR 2018).

As discussed above, there are many examples throughout history of legal harvest of lake sturgeon at levels previously thought to be adequately protective that have later been shown to be unsustainable. In Minnesota itself for example, restrictions for the Minnesota-Canada border fishery began to tighten in 2000 in response to increasingly heavy fishing pressure: the fishing season was closed from May 15–June 30 to protect spawning runs and there was a minimum legal size limit of 45 inches; in 2002 the fishing season was closed from May 1–June 30 with a legal size slot limit of 45–55 inches (Williamson 2003, pp. 130-131). In 2003, the Minnesota Department of Natural Resources stated that changes to existing regulations were being proposed (MNDNR 2003) due to evidence that lake sturgeon populations within Minnesota may not be sustainable with current catch levels continued (Welsh 2004, p. 318). Minnesota allowed sport harvest of lake sturgeon in the Assiniboine and Red River basins in northern Minnesota until 2006, where there was no recent evidence of naturally reproducing populations (COSEWIC 2006). Only catch-and-release of lake sturgeon is now allowed in the Red River in Minnesota (MNDNR 2018).

Mississippi

The lake sturgeon is not classified as endangered or threatened in Mississippi (Williamson 2003, pp. 17-18).

All commercial and sport fishing for lake sturgeon is closed (Williamson 2003, pp. 17-18); and harvest and possession of all sturgeon species is prohibited in all Mississippi waters (MWFP 2015, 2017).

Missouri

The lake sturgeon is a state listed endangered species in Missouri (Williamson 2003, pp. 17-18). Management goals within the state include protection from fishing, reestablishing self-sustaining populations, habitat improvement, river management, and artificial propagation; while meeting these goals would undoubtedly help sturgeon recovery, it is unknown when and how steps will be implemented to achieve them (MODNR 2013, p. 27).

Lake sturgeon are on the ‘do not harvest” list in Missouri (MDOC 2016, 2018). In 2010 the Missouri Department of Conservation terminated commercial harvest of shovelnose sturgeon and shovelnose-pallid sturgeon hybrids where they commonly coexist with pallid sturgeon in Missouri, to protect federally endangered pallid sturgeon populations. However the year-round sport fishing season for shovelnose sturgeon continues in Missouri, with a daily limit of 10 sturgeon, 30” maximum length (MDOC 2016, 2018). The continued sport fishery for shovelnose sturgeon creates the potential for angler misidentification and inadvertent harvest of lake sturgeon.

Nebraska

In Nebraska, the lake sturgeon is a state threatened species; fishing for lake sturgeon is prohibited and they are illegal to possess (NGPC 2013, 2015). The Nebraska Natural Legacy Project lists lake sturgeon as a "Tier 1 At-Risk Species" (NGPC 2014).

Nebraska allows sport harvest of shovelnose sturgeon (except on the Missouri River upstream from the mouth of the Big Sioux River), with a bag limit of 10 sturgeon and a possession limit of 20 (NGPC 2016). Nebraska is doing outreach within the state to minimize confusion between sturgeon species; the Nebraska Game and Parks Commission cites an incident where anglers thought they had caught the largest shovelnose sturgeon on record, when in fact they had caught a federally and state endangered pallid sturgeon (NGPC 2012).

New York

Lake sturgeon are listed as a threatened species under New York's Environmental Conservation Law (Williamson 2003; Welsh 2004). Unlike many other states, New York's Environmental Conservation Law (New York Consolidated Law Service ECL §11-0535) includes "habitat interference" under the state's definition of "take" for endangered and threatened species. This could discourage habitat destruction and preserve critical spawning areas for the lake sturgeon.

A New York state recovery plan was first developed in 1994 and revised in 2000 and 2005 (Carlson et al. 2002; Carlson 2005). The initial recovery goal was to establish five lake sturgeon populations in individual waters. This was later expanded to maintain populations in five waters and restore populations in three other areas (Carlson 2000). The recovery plan focused on increasing current populations through harvest restrictions and habitat enhancement in state waters, as well as re-establishment of lake sturgeon stocks in several locations. New York released an updated recovery plan in 2018 (NYSDEC 2018). The revised recovery plan defines Management Units across New York: Lake Erie, Western Lake Ontario, Central New York, Eastern Lake Ontario, Upper St. Lawrence River, Lower St. Lawrence River, and Lake Champlain. The recovery plan goal is self-sustaining populations of lake sturgeon in each management unit of at least 750 spawning adults across all spawning aggregations and detection of at least three years of wild reproduction in a five-year period (NYSDEC 2018). The NYSDEC stocking program is seeking to enhance the genetic diversity of stocked sturgeon populations; and spawning habitat enhancement is taking place at several locations in the St. Lawrence River and the Seneca River (NYSDEC 2018). NYSDEC seeks to gather enough evidence of recovery of lake sturgeon to initiate removal from the list of threatened species in New York no later than 2024 (NYSDEC 2018).

Fishing for or possession of lake sturgeon (as well as Atlantic and shortnose sturgeon) is prohibited in New York, including catch and release (NYSDEC 2017).

North Carolina

The lake sturgeon is listed by North Carolina as a "special concern species" (NCWRC 2014). It is unlawful to take or possess any species of special concern, including sturgeon, from the inland waters of North Carolina (NCWRC 2017). There is no open fishing season for lake sturgeon within North Carolina and any sturgeon caught must be immediately released (NCWRC 2017). Very little information is available on lake sturgeon management within North Carolina.

North Dakota

The lake sturgeon is not a listed species in North Dakota (NDGFD 2012).

Although lake sturgeon is considered a game fish (as are pallid and shovelnose sturgeon), all sturgeon fishing was closed in North Dakota in 1990 (NDGFD 2016). It is illegal to take, possess or transport lake sturgeon in North Dakota, and any incidentally caught lake sturgeon must be immediately released back into the water from which they were caught (NDGFD 2016).

Ohio

The state of Ohio has listed the lake sturgeon as an endangered species (Williamson 2003; Welsh 2004), but no active lake sturgeon management had been initiated in the state as of 2004 (Welsh 2004, p. 320). Possession and take of lake sturgeon is prohibited in Ohio, and sturgeon must be returned unharmed to the water immediately if caught (ODNR 2015b, 2018).

Pennsylvania

The lake sturgeon is listed as an endangered species in the state of Pennsylvania (Williamson 2003; Welsh 2004; PFBC 2015). Pennsylvania had no recovery plans or active management of lake sturgeon as of 2004 (Welsh 2004, p. 320).

There is no fishing season for sturgeon in Pennsylvania, and catching, taking, killing, possessing, importing, exporting, selling or purchasing of any sturgeon species is prohibited (PFBC 2018).

South Dakota

The lake sturgeon is not classified as endangered or threatened in South Dakota (Welsh 2004), but commercial and sport fishing is closed year-round on all sturgeon species in South Dakota and no sturgeon can be harvested (SDGFP 2018).

Tennessee

The lake sturgeon is listed as an endangered species in Tennessee (TWRA 2012). No harvest of any sturgeon species is allowed in Tennessee; all sturgeon must be released if incidentally caught (TWRA 2018).

Vermont

The lake sturgeon is listed as an endangered species in the state of Vermont and is considered a “greatest need species” by the Vermont Fish and Wildlife Department (VTFW 2005, p. 3-6). Vermont released a Lake Champlain lake sturgeon recovery plan in 2016, with a restoration goal of 2,000 mature adult sturgeon in the lake or 750 mature adults for each population spawning in the Missisquoi, Lamoille, and Winooski rivers

(VTFW 2016). Anglers may not target lake sturgeon and must release them unharmed if caught (VTFW 2018).

West Virginia

West Virginia does not have a state endangered species act, and thus the lake sturgeon is not listed within West Virginia (Welsh 2004; WVDNR 2012). The lake sturgeon has not been recorded in West Virginia since at least the 1940s (Cincotta 2004) and is likely extirpated from the state (WVDNR 2015). There is no fishing for lake sturgeon in West Virginia and any sturgeon caught must be returned to the water immediately (WVDNR 2018).

Wisconsin

Lake sturgeon have no formal protection in Wisconsin but are on an unofficial state watch list (Welsh 2004, p. 318). Because they are not a state listed species, lake sturgeon in Wisconsin are not subject to the state's restrictions on take.

The state of Wisconsin has developed a lake sturgeon management plan (Scheidegger 2000) which contains research, management objectives and recommendations. The plan includes goals for population densities, priorities for rehabilitation locations, and recommendations for habitat enhancement. As of 2002, the state of Wisconsin was also conducting status assessments on spawning lake sturgeon populations in the rivers and shorelines of Lake Michigan and Lake Superior (GLLSCM 2002). The state has begun reintroduction programs on the Menominee River, Lake Winnebago, and the St. Louis River (GLLSCM 2002) and restoration of spawning habitat has also taken place in the Lake Winnebago-Wolf River system (Bruch 1999).

Wisconsin allows annual sport harvest of 1 lake sturgeon over 60" per angler in all inland waters open to lake sturgeon hook-and-line angling (Chippewa River, Flambeau River, Wisconsin River, Butternut Lake, Yellow chain of lakes, Wisconsin-Michigan boundary waters, and Wisconsin-Minnesota boundary waters including the St. Croix River, Mississippi River, and St. Louis River), from the first Saturday in September through September 30 (WDNR 2018). Wisconsin also has unlimited lake sturgeon catch-and-release seasons in the Mississippi River upstream of Red Wing Dam (June 16 to March 1), Mississippi River downstream of Red Wing Dam (June 16 to April 14), St. Croix River from Prescott to Gordon Flowage (June 16 to March 1), St. Louis and Nemadji rivers (June 16 to April 14), and the St. Croix River - Wisconsin/Minnesota boundary water (from October 1 to October 15) (WDNR 2018).

Other than in the Flambeau River, where there is a healthy sturgeon population, continued sport fishing of lake sturgeon in these rivers is cause for concern: as discussed above, the sturgeon population is small in the Chippewa River; sturgeon are uncommon to rare in the Wisconsin River; the formerly depleted population in Yellow Lake is being rebuilt through stocking, but lacks older fish; the population is below self-sustaining levels in the St. Croix River; sturgeon are rare in the upper Mississippi River; and restocking in the St. Louis River has only just recently resulted in spawning. A year-round open season on lake sturgeon is allowed in Lake Superior in Wisconsin waters (WDNR 2015b), which is also concerning since so many of the sturgeon populations in Lake Superior tributaries are small and depleted.

There is no lake sturgeon fishing allowed in all other Wisconsin inland waters, the Mississippi River boundary waters, Lake Michigan or the major tributaries to Green Bay and Lake Michigan (the Peshtigo, Oconto, and Milwaukee rivers), or the St. Croix River upstream from the St. Croix Falls Dam (WDNR 2015b). A former sturgeon fishing season in the Menominee River was discontinued after it was found that lake sturgeon were still being overexploited in two out of three river sections despite regulations in place (Thuemler 1997).

The Winnebago system (Lake Winnebago and the Upriver Lakes - Butte des Morts, Winneconne and Poygan), which hosts a large population of lake sturgeon, is closed to hook-and-line fishing but there is a short sturgeon spear fishery open from February 13 to February 28, or until any pre-set harvest caps are reached (WDNR 2015b). The Wisconsin Department of Natural Resources can end spearing as soon as any quota is reached and there are strict regulations on all other parts of this process, from the size that the ice fishing hole can be to the size of the sturgeon, to the time fishing can begin. In 2016 the lake sturgeon caps for the Winnebago spear fishing season were 430 juvenile females, 950 adult females and 1,220 males; the actual 2016 total harvest was much smaller at 703 sturgeon (396 from Lake Winnebago and 307 from the Upriver Lakes).

Wisconsin allows year-round harvest of shovelnose sturgeon on the lower Wisconsin River (from the Prairie du Sac Dam downstream to the confluence with the Mississippi), and on the Mississippi River below the Red Wing Dam (WDNR 2018). This creates the potential for angler misidentification and inadvertent harvest of lake sturgeon.

State Mitigation and Enhancement Measures

Several states have initiated mitigation and enhancement measures and projects to benefit lake sturgeon, including: fish stocking, fish passage projects, dam modification or removal, upstream passage through navigation locks, changing the timing of water-related activities, downstream guidance or diversion, recommending changes in operation of hydroelectric facilities, spawning bed creation and enhancement, and water quality improvements.

There is some concern about restoration efforts using out of basin sturgeon for stocking programs. Drauch and Rhodes (2007) cautioned that lake sturgeon from Lake Winnebago, Wisconsin, which were initially widely used for reintroductions across North America, could potentially homogenize the overall lake sturgeon metapopulation. Welsh et al. (2010) identified appropriate genetic stocking units of lake sturgeon to be used for Great Lakes reintroduction efforts: Most of the more recent reintroduction and stocking programs by states have stocked fish acquired or raised from the same basin, or utilized streamside rearing facilities to grow fish from sturgeon eggs collected from within the same watershed. In some cases where natural lake sturgeon populations have been extirpated from an entire basin, such as in Alabama and Georgia, it may be appropriate to use out of basin sturgeon for reintroductions.

Lake Superior

In the St. Louis River, a 2009 Minnesota Department of Natural Resources project improved roughly 800 feet of suitable lake sturgeon spawning habitat below the Fond du Lac Dam, 34 km upriver from Lake Superior (Abraham and Kallak 2008, p. 13). MNDNR began annual stocking of lake sturgeon fry, fingerlings and yearlings in the St. Louis River in 1983. Initial stocking was with fish from outside the Lake Superior basin and restoration efforts were curtailed for several years due to concerns about use of these fish; since 1998, stocked sturgeon have been propagated from the Sturgeon River, an intrabasin source (Scheidegger 2000). Through 2008 there was no evidence of stocked lake sturgeon spawning in either the lower or upper St. Louis River (Schram et al. 1999; Zollweg et al. 2003; Welsh 2004; Pratt 2008; Abraham and Kallak 2008), but beginning in 2011 was the first evidence of successful lake sturgeon spawning in the St. Louis River since stocking began (Cook 2015).

In the Bad River, lake sturgeon have been taken from the river to be propagated and returned to the Bad River to augment the population (Auer 2003).

In the Ontonagon River, lake sturgeon have been reintroduced (Holey et al. 2010), through stocking with hatchery fish from 1998-2002 and 2004, including sturgeon from the nearby Sturgeon River (Auer 2003; Baker 2006). So far there has been no evidence of reproduction of stocked fish (Filmore 2003; Baker 2006). The Michigan Department of Natural Resources Fisheries Division plans to continue stocking propagated lake sturgeon into the Ontonagon River until 20 year classes have been added.

In the Sturgeon River, a positive change in the spawning characteristics of the lake sturgeon population below the Prickett hydroelectric facility was observed after peaking flows were changed to near run-of-the-river flows (Auer 1996b, pp.69-76).

Western Lake Michigan

Streamside rearing facilities for lake sturgeon have been initiated in four western Lake Michigan tributaries where sturgeon have been extirpated - the Milwaukee, Manitowoc, Cedar and Whitefish rivers (Baker et al. 2008).

In the Menominee River, young sturgeon have been stocked into the upstream river section below Sturgeon Falls for several years (WDNR 2012). State agencies are pursuing fish passage projects for lake sturgeon in the lower Menominee River, including through a FERC relicensing process, at the lower two dams (GLRI 2010; Donofrio and Utrup 2013; Kampa et al. 2014a). A fish bypass will enable downstream-moving sturgeon to get through the upper dam, and an elevator fish lift at the lower dam will help move lake sturgeon upstream. The long-term fish passage goal is to provide passage for lake sturgeon at five hydropower dams on the Menominee River by 2020 (GLRI 2010).

In the Wolf River, lake sturgeon have been stocked since 1994 in lakes on the Menominee Indian Reservation (Runstrom et al. 2002). Transfer of lake sturgeon from the lower Wolf River to several reaches of the Wolf River on the reservation (Keshena Falls 10 km upstream of Balsam Row Dam; Big Eddy Falls 20 km above the dam; and the Dalles 32 km above the dam) resulted in enough adults present in reservation waters in the spring of 2001 that spawning may have occurred in this reach of river for the first time in over 50 years (Runstrom et al. 2002).

Eastern Lake Michigan

In the Muskegon River, the Michigan Department of Natural Resources is planning to initiate a streamside sturgeon rearing station which will collect drifting sturgeon eggs and larvae in the spring, rear them, and release them back to the river in the fall; with a goal of restoring a minimum sturgeon population of 300 adults (Meyerson 2013).

A streamside rearing facility is being used to increase the survival of naturally produced larvae in the Manistee River (Holtgren et al. 2007). In the Big Manistee River, the Little River Band of Ottawa Indians (LRBOI) has operated a streamside rearing facility since 2004, aimed at increasing the survival of naturally produced lake sturgeon larvae, with stocking of fingerling lake sturgeon raised from larvae collected and reared in the Big Manistee River (Holtgren et al. 2007; LRBOI 2008). The LBROI restoration target is 750 adult fish (LRBOI 2008).

Northwestern Minnesota

Since 1994, 5 of the 8 dams on the mainstem of the Red River in the U.S. have been modified to allow sturgeon passage, and another 19 dams have been modified or removed on tributaries (Abraham and Kallak 2008); there are plans to remove or modify many more dams (MNDNR 2002).

The Minnesota Department of Natural Resources (MNDNR) first began lake sturgeon restoration stocking in 1997, and in 2002 began implementing a 20-year reintroduction plan to restore lake sturgeon throughout the Red River basin (MNDNR 2002). Lake sturgeon fry and fingerlings from the Rainy River are stocked into Red River basin rivers and lakes, with a goal of reestablishing a naturally reproducing population over the next 20 to 30 years (COSEWIC 2006). Reintroduction is planned for the Buffalo, Otter Tail, Red Lake, Roseau, and Wild Rice tributaries, as well as Big Detroit, Round and White Earth lakes (Aaland et al. 2005, pp. 307-308). The MNDNR and the White Earth Ojibwe Nation have been stocking about 20,000 fingerlings annually into Red River lakes and tributaries in the U.S.; MNDNR has also stocked an average of over 150,000 fry each year (MNDNR 2002; Aadland et al. 2005; Abraham and Kallak 2008).

Upper Mississippi River

In the upper Mississippi River, restoration stocking using lake sturgeon of Wisconsin origin began in 1984, with release sites at Lagrange, Shanks Conservation Area, and Louisiana, Missouri (MDOC 2007). The lake sturgeon stocked prior to 2002 came from the Wolf River in Wisconsin, in the Lake Winnebago system (Great Lakes Basin). Beginning in 2002, the egg source has been the Wisconsin River, a tributary to the Mississippi River. Future stockings will be from eggs obtained by the Wisconsin Department of Natural Resources from the Mississippi River basin (MDOC 2007. Stocked lake sturgeon are now encountered on the Mississippi River by anglers and biologists from Pool 20 below Keokuk, Iowa downstream to Chester, Illinois, and in some of the larger tributaries in Missouri, Nebraska, and Illinois, but there is no known reproduction and populations are far from self-sustaining (MDOC 2007).

In the Kettle River tributary of the St. Croix River, Sandstone Dam was removed in 1995, potentially restoring spawning habitat and reconnecting a historically important tributary on the upper river (Abraham and Kallak 2008, p. 13). However, years of accumulated sediment from behind the dam washed downstream, covering known spawning sites and filling in important deep pool habitat river (Abraham and Kallak 2008).

In the Namekagon River tributary of the St. Croix River, the Wisconsin Department of Natural Resources (WDNR) began stocking hatchery-reared lake sturgeon (from a genetically appropriate source above the dam) below Trego Dam in 1993 and protecting stocked fish from harvest with a closed lake sturgeon fishing season in the Trego Flowage and the Namekagon River upstream from the flowage (Kampa et al. 2014b). The WDNR is considering fish passage options at the Trego Dam to allow upstream passage of naturally recruited fish (Kampa et al. 2014b).

In the Yellow River tributary of the St. Croix River, WDNR stocked 10,000 fry and 13,000 fingerlings in 1995 and similar rearing and stocking efforts continued through 2000 (WDNR 2000).

In the Flambeau River, a restoration stocking program has captured adult lake sturgeon from the Flambeau River since 1993 to propagate fingerlings and fry that are restocked into the Flambeau Flowage system (WNRM 2009).

In the Manitowish River, brood stock of lake sturgeon were collected from the river in 1998 and 24,000 fingerlings were stocked back into the river (Scheidegger 2000). Attempts were also being made to collect and spawn lake sturgeon from the North Fork of the Flambeau River for stocking of fry and fingerlings into the Manitowish River (Scheidegger 2000).

In the Wisconsin River, a FERC relicensing process will provide future fish passage for lake sturgeon past the Prairie du Sac Dam (Kampa et al. 2014a). A restoration stocking program was begun from 1991-1992 in the Wisconsin River, with juvenile sturgeon transferred from Lake Wisconsin to the lower Wisconsin River; and hatchery-reared fingerlings taken from below the Wisconsin Dells Dam re-stocked in the upper Wisconsin River below the Du Bay Dam from 1997-2002 (DTO 2002). The WDNR augmented the Wisconsin River lake sturgeon population with stockings of juvenile lake sturgeon in 2010 and 2012 (WDNR 2013).

In the Baraboo River, removal of 7 dams was completed by 2001, which will potentially allow lake sturgeon to move into the upper reaches of the Baraboo River for spawning (WDNR 2013).

In the Salt River, lake sturgeon of Wisconsin origin have been stocked recently into Mark Twain Lake (MDOC 2007).

Missouri River

Reintroduction of lake sturgeon by the Missouri Department of Conservation first began in the lower Missouri River in 1984 (Drauch and Rhodes 2007). Stocking of fingerling lake sturgeon from Lake Winnebago has occurred since 1992 (Drauch and Rhodes 2007; MDOC 2007), with release sites in Cooley Lake, Waverly, Boonville, Mokane, Hermann, Washington and New Haven, Missouri (MDOC 2007). Stocked lake sturgeon are now encountered by anglers and biologists up the Missouri River to the tailwaters of Gavins Point Dam (MDOC 2007), but there is no known reproduction and the population is far from self-sustaining (MDOC 2007).

Ohio River

In the Ohio River basin, stocking of hatchery lake sturgeon has begun in the Cumberland and Tennessee Rivers as well as the French Broad River in Kentucky and Tennessee (TWRA 2012; KDFWR 2014); but some of the out of basin source populations may not be appropriate for restoration.

Arkansas-White River

No information could be located regarding fish stocking or lake sturgeon restoration projects in the Arkansas-White River.

Lower Mississippi River

Beginning in 1984, the Missouri Department of Conservation began stocking fingerling lake sturgeon from Lake Winnebago into the lower Mississippi River in Louisiana (Drauch and Rhodes 2007).

Other Natural or Anthropogenic Factors

Invasive Species

Invasive species can disrupt the food web, alter habitat structure, and introduce new diseases for sturgeon (Pratt 2009 p. 28).

<u>Zebra and Quagga Mussels</u>

The zebra mussel (*Dreissena polymorpha*), an invasive freshwater species native to lakes of southern Russia, represents a recent threat to lake sturgeon populations and recovery programs. Zebra mussels now occur across much of the lake sturgeon's range (Wesley and Duffy 1999, p. 64; McCabe et al. 2006). Despite being part of the diets of larger sturgeon, zebra mussels are known to impede the foraging success of younger sturgeon, alter habitat selection, and be detrimental to many restocking programs (Jackson et al. 2002; McCabe et al. 2006; Criswell 2014). Juvenile lake sturgeon utilize sandy and silty habitats, the preferred habitat of zebra mussels, which fill the area with shells (McCabe et al. 2006). Zebra mussels are often found on soft sediments and in water between 3 and 90m deep (Dermott and Munawar 1993; Coakley et al. 1997; Dermott and Kerec 1997) and may block juvenile sturgeon access to preferred invertebrate food sources. High concentrations of zebra mussels can prevent juvenile sturgeon from recognizing areas as potential foraging grounds (McCabe et al. 2006, p. 2,5). Smaller sturgeon, which mainly consume amphipods, experience a reduction in foraging success in areas where zebra mussels are present. Lake sturgeon foraging success on amphipods and isopods was greatly reduced by just 50% zebra mussel cover (McCabe et al. 2006, p.6). Beekey et al. (2004b) found that lake sturgeon experienced up to 90% reduction in foraging success when zebra mussels were present.

There is currently no known management solution for zebra mussels in lake sturgeon habitat. Their spread has the potential to greatly affect lake sturgeon restoration in the Great Lakes, where zebra mussels are currently thriving (Carlson 2000; McCabe et al. 2006, p. 7). Zebra mussels are now established in Lake Michigan and found in the mouth of St. Joseph River (Wesley and Duffy 1999, p. 64). Both zebra and quagga mussels have colonized vast areas of the bottom of Lake Erie (Criswell 2014)

Quagga mussels (*Dreissena bugensis*) have spread throughout the Great Lakes since the 1990s. The presence of Botulism-E toxin has been noted in the stomachs of lake sturgeon following the consumption of quagga mussels (Stone and Okoneiwski 2002).

Climate change is expected to facilitate increases in the populations of zebra and quagga mussels in the Great Lakes (Huff and Thomas 2014, p. x-xi).

<u>Rusty Crayfish</u>

Rusty crayfish (*Orconectes rusticus*) is an invasive species and opportunistic feeder that has been introduced to the Great Lakes, with negative impacts on lake sturgeon as well as populations of macroinvertebrates (Wesley and Duffy 1999 p. 16). Rusty crayfish prey on lake sturgeon eggs (Scribner and Baker 2008; Caroffino et al. 2010; MSU and MDNR 2015) and are potential predators of larval lake sturgeon.

Round Goby

The round goby (*Neogobius melanostomus*) is an invasive fish from the Black Sea, likely also introduced by ballast water, whose numbers have exploded in Great Lakes beginning in the 1990s (Criswell 2014; MSG 2016). Round goby are known to prey on lake sturgeon eggs (Kempinger 1988; Nichols et al. 2003; Caroffino et al. 2010; MSU and MDNR 2015).

The presence of Botulism-E toxin has been noted in the stomachs of lake sturgeon following the consumption of round gobies (Stone and Okoneiwski 2002). Round gobies were the suspected cause of a 2001 botulism outbreak in eastern Lake Erie that killed at least 20 lake sturgeon (Criswell 2014). This consumption of infected hosts may explain increased lake sturgeon mortality observations from 1999-2009 in Lake Ontario and Lake Erie (Chalupnicki et al. 2011).

Round gobies eat large quantities of zebra mussels, but it is unlikely that gobies alone will have a detectable impact on zebra mussel densities (MSG 2016).

Jacobs et al. (2017) looked at invasive species-induced ecosystem change precipitated by Dreissenid mussels (*Driessena polymorpha* and *Driessena bugensis*) and round goby in the lower Niagara River and nearby Lake Ontario. Jacobs et al. (2017) analyzed fin rays from lake sturgeon captured in 1998–2000 and 2010–2012 for stable isotopes to assess sturgeon diet, and conducted diet analysis of lake sturgeon captured in 2014 to assess the contribution of invasive prey. Jacobs et al. (2017) found that: round goby was the most important lake sturgeon prey item (86% by weight) in 2014; round goby have very likely become the most important prey item for Niagara River lake sturgeon; and that sturgeon are able to access a higher trophic level at a younger age and smaller size than prior to the goby invasion. Lake sturgeon in this system may have exploited a higher diversity of prey items prior to the round goby invasion, but round goby establishment corresponds with increased sturgeon prey fish consumption, and also higher somatic growth rates for juvenile and subadult lake sturgeon. Jacobs et al. (2017) concluded that round goby establishment in western Lake Ontario changed the feeding ecology of lake sturgeon, which may have a positive effect on population growth for sturgeon. Jacobs et al. (2017) postulated that round goby acted as an energetic pathway through which sturgeon access high biomass accumulated by Dreissenid mussels. Lake sturgeon now reach a higher trophic level at a younger age and smaller size than lake sturgeon captured prior to the round goby invasion. Shifts in diet to larger, more energy dense higher-trophic level prey is generally associated with higher fitness in fishes.

Jacobs et al. (2017) cautioned that an alternative explanation could be that their results reflect a new differential mortality regime, perhaps driven by increased competition for invertebrate prey between round goby and non-piscivorous lake sturgeon, a possibility that may warrant further investigation. Such a recruitment bottleneck could lead to increased growth rates due to reduced intraspecific competition among surviving juvenile lake sturgeon, but intraspecific competition is not expected to be strong in this system as lake sturgeon abundance appears quite low in both time periods compared to historical accounts. Jacobs et al. (2017) recommended that future research efforts should focus on whether individual fitness benefits of round goby consumption translate to increased sturgeon population growth, or whether these benefits are offset by other factors they did not investigate, including increased egg predation by round gobies or negative effects of interspecific competition at small lake sturgeon body size.

Sea Lamprey

The sea lamprey (*Petromyzon marinus*) is an invasive species that was accidentally introduced into the Great Lakes in the early 20th century through shipping canals. Lampreys parasitize and feed on large native fish. In the Great Lakes, sea lamprey are known to predate mostly on lake trout, salmon, rainbow trout (steelhead), whitefish, chubs, burbot, walleye and catfish (GLFC 2000). Sea lamprey also attack and parasitize lake sturgeon and are thought to kill smaller lake sturgeon in the Great Lakes (GLFC 2007).

Climate change is expected facilitate increases in the populations of sea lampreys in the Great Lakes due to warmer waters and longer growing seasons (NWF 2013, p. 16; Huff and Thomas 2014).

Other Invasive Fish

Introduced common carp (*Cyprius carpio*) are known to feed on lake sturgeon eggs (Kempinger 1988; Nichols et al. 2003; Caroffino et al. 2010).

Introduced non-native salmonids may prey on drifting lake sturgeon larvae (Auer and Baker 2002; Auer et al. 2003).

Invasive Plants

Invasive plants such as purple loosestrife (*Lythrum salicaria*) and Eurasian milfoil (*Myriophyllum spicatum*) are expected to have negative impacts on native fish and the populations of macroinvertebrates that support them (Wesley and Duffy 1999, p. 16).

Climate Change

Earth's climate system is rapidly changing, with widespread impacts projected to occur on inland aquatic systems. Climate change effects with the greatest significance for North American aquatic ecosystems include warming of the atmosphere and oceans, reduced snow and ice, and rising sea levels (IPCC 2014). Dramatic changes in precipitation patterns have already been observed, with wet regions becoming wetter and dry and arid regions becoming drier (Chou et al. 2013). For example, Arctic regions have experienced increased precipitation, whereas southern Canada has seen a significant decrease in spring snow extent (Dore 2005). Winter precipitation is predicted to increase at higher latitudes, and summer precipitation is expected to decrease in the southeastern United States (Dore 2005), with variability in precipitation increasing throughout the continent. Continental temperatures have progressively warmed, particularly at higher latitudes (IPCC 2014; Walsh et al. 2014). This warming has driven significant changes in spring snow accumulation and runoff timing in the western United States, causing significant hydrologic changes and, in the most extreme cases, hydrologic regime shifts (e.g., snowmelt driven to transient rain-on-snow; Mote et al. 2005; Stewart et al. 2005). Observed trends in snowmelt hydrology in the western United States are expected to continue into the future, particularly near the margins of heavy snowfall areas (Adam et al. 2009). Moreover, the frequency of extreme climatic events (e.g., <10th or >90th percentile daily means in temperature or precipitation within a season) is predicted to increase across North America (Saha et al. 2006).

Climate change is already causing a rise in temperatures across the United States and an increase in extreme weather events, such as droughts (Parmesan et al. 2000; NSC 2003; CCSP 2008; Karl et al. 2009). Climate change predictions for terrestrial areas in the Northern Hemisphere indicate warmer air temperatures, more intense precipitation events, and increased summer continental drying (Cayan et al. 2005; IPCC 2007). In the United States, the average surface temperature rose by 1.8°F (1.0°C) between 1901 and 2016, with the most rapid warming occurring since 1979 (USGCRP 2017). By mid-century, the average temperature in the United States is expected to increase by 2.5°F (1.4°C) relative to 1976-2005, meaning that record-setting hot years will become commonplace during the next few decades (USGCRP 2017). By late century, much greater warming is projected, ranging from 2.8 to 7.3°F (1.6 to 4.1°C) under a lower emissions scenario and 5.8 to 11.9°F (3.2 to 6.6°C) under a higher emissions scenario (USGCRP 2017). Global carbon emissions over the past 15 to 20 years have tracked the highest emission scenario used in IPCC climate projections, which is projected to lead to devastating impacts (IPCC 2014).

Climate change has the potential to dramatically impact lake sturgeon. Lake sturgeon have evolved in accordance with specific hydrologic regimes and habitat niches. Water flow and temperature influence lake sturgeon spawning and recruitment success. Flow regimes in lake sturgeon rivers will change with a changing climate, with differences in seasonal timing of river flow and temperature likely to have negative impacts on sturgeon. Fish such as lake sturgeon that rely on specific temperature conditions for success of spawning, juvenile recruitment, and embryo development will be affected by increases in ambient temperatures (Ficke et al. 2007, p. 594, 595, 598). Rising water temperatures can be expected to greatly decrease the quality and quantity of spawning and nursery habitats for lake sturgeon. Climatic variability could also disrupt the timing of sturgeon reproduction and the length of optimal fish growth periods as environmental cues shift and warming waters affect stream ecological processes and ecosystem health. For example, a study of lake sturgeon in the St Lawrence River found that climatic and hydrological conditions in June, when larvae drift from the spawning grounds and exogenous feeding begins, are critical determinants of year-class strength (Nilo et al. 1997).

Climate change is expected to increase water temperatures, decrease dissolved oxygen, and increase toxicity of pollutants in freshwater systems (Ficke et al. 2007, p. 581). The temperate regions that lake sturgeon inhabit are expected to experience much larger temperature changes than tropical areas (Ficke et al. 2007, p. 594). Increasing temperatures in North American streams may result in nearly a 50% decrease in cold and cool water fish habitat (Ficke et al. 2007, p. 586). Endemic freshwater fish species and those in fragmented habitats will be less able to adapt to changing thermal conditions (Ficke et al. 2007, p. 581,603).

Kaushal et al. (2010) analyzed historical records from 40 sites around the U.S. and found that 20 major streams and rivers have shown statistically significant, long-term warming of water temperatures, typically correlated with increases in air temperatures and urban areas. Kaushal et al. (2010) cautioned that if stream temperatures were to continue to increase at current rates, due to global warming and urbanization, this could have important effects on eutrophication, ecosystem processes such as biological productivity and stream metabolism, contaminant toxicity, and loss of aquatic biodiversity.

Lake sturgeon reproductive activities are greatly influenced by the temperature of the surrounding environment. Male and female lake sturgeon not only differ in spawning periodicity, but also require specific temperature ranges. Climate change and associated temperature shifts are expected to create changes in lake sturgeon phenology and have the potential to render populations of the species largely nonviable. Recruitment of juveniles and embryo growth and development for freshwater fish also depend on water temperature (Wang et al 1985; Ficke et al. 2007, p. 595). Wang et al (1985) found that lake sturgeon embryos exhibit optimal survival between just 14-17° C with incipient mortalities beginning around 20°C. Increased temperatures may also generate hypoxic episodes; depleted oxygen will likely reduce embryo growth rates and the overall reproductive output of fresh water fish species (Ficke et al. 2007, p. 598).

Climate change is also expected to alter immunity and parasitism for fresh water fish species. Temperature shifts will affect host-parasite dynamics by causing an increase in transmission opportunities, leading to an increased parasite load in temperate fishes (Ficke et al. 2007, p. 600-601). Changing global temperatures are expected to compromise the immunity of fish as well as reduce their immune response in the face of other threats such as crowding, high temperatures, or osmotic stress (Ficke et al. 2007, p. 601). When paired with high temperatures, the toxicity of common pollutants generally increases (Ficke et al. 2007, p. 585).

Changes in the productivity of water bodies are also anticipated in response to climate change. Increases in mean temperatures will increase fish metabolism and decrease lake turnover, thereby depleting dissolved oxygen faster and replenishing it less often (Ficke et al. 2007, p. 590). Increased temperatures in lakes could result in eutrophication since algal growth and nutrient cycling rates are both highly dependent on temperature (Ficke et al. 2007, p. 588).

Lynch et al. (2016) conducted a literature review of the empirically documented effects of climate change on North American inland fish populations (e.g., changes to distribution, phenology, abundance, growth, recruitment, genetics) and assemblages structure (i.e., species richness, evenness, and composition). Lynch et al. (2016) identified several major themes in North American inland fish responses to climate change: shifts in species' spatial distributions and the timing of key behaviors (e.g., migrations, spawning); changes to abundance, growth, and recruitment; species interactions are often the proximate driver of climate-induced changes in fish population dynamics and extirpation; and complex interactions between climate change and other anthropogenic stressors (such as altered land use, water pollution, stream and river impoundments and flow alterations, invasive species, disease and parasites, and fishing exploitation). Lynch et al. (2016) also note that a small number of studies indicate that North American inland fishes are already exhibiting genetic change due to climate changes.

Whitney et al. (2016) described the observed and potential effects of climate change on the physiology of freshwater fishes in North America, particularly neuroendocrine, cardiorespiratory, immune and reproductive effects. Their key findings were that climate change may: result in chronically elevated environmental stressors that challenge the neuroendocrine system of some fishes, elevating metabolic costs and decreasing growth and survival; expose some fishes to thermal conditions outside of their species- or population-specific optimal thermal range for aerobic scope; elicit hyperactive or suppressive responses from fish immune systems, both of which may result in compromised immune function; and influence reproductive timing and investment of fishes due to deviations from optimal temperatures and dissolved oxygen, potentially reducing reproductive output and success.

Climate change impacts in the Midwest and Great Lakes region are expected to exacerbate a range of risks to the Great Lakes ecosystem, including changes in the range and distribution of certain fish species, increased invasive species and harmful blooms of algae (Pryor et al. 2014, p. 426). Climate change is expected to cause higher water temperatures in the Great Lakes basin, both positive and negative changes in precipitation, decreases in riverine runoff, less snowfall and snowpack accumulation, higher evapotranspiration, and a reduction in lake levels and connecting channel flows (Mortsch and Quinn 1996). These climate and hydrologic changes will affect the quantity and quality of wetland and aquatic habitats, alter the frequency and timing of lake turnover, and change dissolved oxygen, and alter fish community composition and dynamics (Mortsch and Quinn 1996). The Great Lakes are already recording higher water temperatures and reduction in ice cover as a result of changes in regional climate between 1968 and 2002 - summer surface water temperatures in Lakes Huron increased 5.2°F, Lake Ontario 2.7°F, and Lake Superior 4.5°F - these lake surface temperatures are projected to rise by as much as 7°F by 2050 and 12.1°F by 2100 (Pryor et al. 2014, p. 426). Higher temperatures, increases in precipitation, and lengthened growing seasons favor production of blue-green and toxic algae that can harm fish and water quality, and could heighten the impact of invasive species (Pryor et al. 2014, p. 426).

Annual temperatures in the Great Lakes region are projected to increase 1.4 °C over the near-term (2010–2039), by 2-3 °C by midcentury (2040–2069), and by 3-5 °C by end-of-century (2070–2099), relative to the historical reference period 1961–1990 (Hayhoe et al. 2010). Angel and Kunkel (2010) predicted a wide range of lake-level changes for the Great lakes based on various climate change scenarios. Hartmann (1990) predicted increased water temperatures and depleted oxygen in the Great Lakes due to climate change, with potential lowering of Great Lakes levels that could dramatically affect ecosystem production through dependence on the consistent availability of marshes and wetlands that serve as breeding and nursery areas for fish and wildlife.

Warmer air temperatures are likely to lead to increasing water temperatures and changes in summer stratification in the Great Lakes and in the inland lakes and streams of the region (Kling et al. 2003, p 21). Earlier model studies project that summer surface water temperatures in inland lakes will increase by 2 to 12°F (1 to 7°C), but projected changes in water temperature could be even greater using more recent climate scenarios, especially by 2090 (Kling et al. 2003, p 21). Projections for deep water range from a 14°F warming to a counterintuitive 11°F cooling (the response in deep waters varies because warming air temperatures can cause a small, deep lake to stratify sooner in spring, at a cooler temperature (Kling et al. 2003, p 21). Overall, changes in temperature and stratification will affect the fundamental physical, chemical, and biological processes in lakes - higher water temperatures, for example, result in lower oxygen levels (Kling et al. 2003, p 21).

In a warming climate, the duration of summer stratification will increase in all the lakes in the Great Lakes region. Longer stratification periods and warmer bottom temperatures will increase oxygen depletion in the deep waters of the Great Lakes and will lead to complete loss of oxygen during the ice-free period in many inland lakes of at least moderate depth. Anoxia or hypoxia in deep waters will have negative impacts on most of the organisms in the lakes. Persistent dead zones can result in massive fish kills and damage to fisheries. (Kling et al. 2003, p 23)

Climate change will have complex impacts on primary productivity in the Great Lakes. It could lead to changes in the species composition of algae and in seasonal patterns of blooms, shift in the timing of spring algal bloom, shift in dominance in the algal community during the growing season from diatoms to inedible blue-green algae, potential dominance by inedible, nuisance species of algal productivity, or timing of algal production out of synch with the food demands of fish (Kling et al. 2003, pp 24-25). In the river and stream ecosystems of the Great Lakes, climate change is expected to lower summer water levels and raise stream temperatures (Kling et al. 2003, pp 25-26).

In Lake Superior, climate change is expected to increase annual average water temperatures in the lake by approximately 5 to 7 ºC throughout the 21st century, decrease the abundance of cold water fish and increase abundance of warm water fish, reduce fish productivity as a result of changes in thermal stratification, lead to declines in the population and health of fish dependent upon cold, well-oxygenated water, and facilitate increases in the populations of aquatic invasive species such as sea lampreys and zebra and quagga mussels (Huff and Thomas 2014, p. x-xi).

Lyons and Stewart (2014) identify river reaches in Wisconsin where lake sturgeon might be vulnerable to warming water temperatures due to climate warming. Although the exact temperature tolerances are uncertain, water temperatures above 28–30°C are potentially less suitable for this coolwater species. Predictions from 13 downscaled global climate models were input to a lotic water temperature model to estimate amounts of potential thermally less-suitable habitat at present and for 2046–2065: currently, 341 km (14.9%) of the known habitat are estimated to regularly exceed 28°C for an entire day, but only 6 km (0.3%) to exceed 30°C; in 2046–2065, 685–2164 km (29.9–94.5%) are projected to exceed 28°C and 33–1056 km (1.4– 46.1%) to exceed 30°C (Lyons and Stewart 2014). Most river-lake networks have cooler segments, large tributaries, or lakes that might provide temporary escape from potentially less suitable temperatures, but 12 short networks in the Lower Fox and Middle Wisconsin rivers totaling 93.6 km are projected to have no potential thermal refugia (Lyons and Stewart 2014).

Habitat Fragmentation

A prominent anthropogenic threat inhibiting recovery of lake sturgeon populations is habitat fragmentation (Hay-Chmielewski and Whelan 1997, p. 31; Auer 1999; Peterson et al. 2007). Natural barriers, such as fast flowing rapids or small waterfalls, may not fragment habitat or population connectivity (Welsh and McLeod, 2010) however artificial barriers such as hydroelectric developments or water diversions have resulted in severely fragmented habitats, isolated populations, and altered spawning behavior (Paragamian et al. 2001; Haxton, 2002; Daugherty et al. 2008a, 2008b). Barriers to sturgeon migration prevent the use of optimal habitats for each lake sturgeon life stage systems (Hay-Chmielewski and Whelan 1997, p. 31). Extensive damming has immediate impacts on lake sturgeon, as it reduces potential range sizes and fragments existing populations (Ferguson and Duckworth 1997; Cooke et al. 2002; Dadswell 2006).

This petition discusses such fragmentation and isolation of lake sturgeon populations in numerous rivers and watersheds due to dams, such as the Menominee River (Priegel 1973; Baker 1980; Thuemler 1997; Hayes and Caroffino 2012; WDNR 2012), Niagara River downstream of Niagara Falls (Carlson 1995), St. Lawrence River (Pratt 2008), Cheboygan River in the Lake Huron watershed (Godby et al. 2011), St. Lawrence River watershed (Pratt 2008), Saskatchewan River watershed (McLeod 1999), and the Nelson River and components of Southern Hudson Bay/James Bay in Canada (COSEWIC 2006).

Auer (1996) estimated that lake sturgeon may require 250 to 300 km of unimpeded river-lake habitat as a minimum home range size to complete their life cycle, without which populations may become vulnerable to extirpation when habitat is severely impacted or unreachable (Harkness and Dymond 1961; Baker and Borgeson 1999). The effects of habitat fragmentation can be delayed, as lake sturgeon populations occupying impounded sections of rivers have lesser abundance and slower growth rates compared to populations residing in unimpeded stretches of rivers (Haxton, 2002, 2003a; Haxton and Findlay 2008).

Lyons and Stewart (2014, p. 1) looked at fragmentation of lake sturgeon populations in Wisconsin, where the 2,291 km of large-river habitat occupied by lake sturgeon has been fragmented into 48 discrete river-lake networks isolated by impassable dams. Lyons and Stewart (2014) found that predicted climate change may make summer river habitat less suitable thermally for lake sturgeon, and that habitat fragmentation by dams may trap lake sturgeon in “marginal” or “stressful” river reaches and prevent them from accessing thermal refugia. Ficke et al. (2007, p. 581,603) found that freshwater fish species in fragmented habitats will be less able to adapt to changing thermal conditions.

Fragmentation of lake sturgeon populations by dams is also known to erode the genetic diversity in fish populations (Ferguson and Duckworth 1997, pp. 303-304; Rieman and Allandorf 2001). Isolation of sturgeon populations makes them vulnerable to extinction (Jager et al. 2001), as confined stocks are at greater risk of extirpation from disease, impacts of pollution or natural catastrophic events (Auer 1999, p. 291).

Vulnerable Life History Characteristics

Inherent biological characteristics of lake sturgeon such as delayed maturity, longevity, and low reproductive output make populations particularly susceptible to decline (Haugen 1969; Beamesderfer and Farr 1997). Lake sturgeon life history characteristics such as late age at sexual maturity and intermittent spawning combined with historic declines and locally extirpated spawning populations makes lake sturgeon rehabilitation very difficult (Auer 2003, p. 4). Sturgeons have evolved a strategy of slow growth, delayed maturity and periodic spawning that has been successful for millions of years, and under natural conditions have overcome predation risks and kept natural mortality low after the first year of life (Houston 1987). These traits buffered extremes in environmental conditions and contributed to the success of the species. However, in the face of intensive overexploitation and habitat loss, these traits have now put them at a disadvantage against human-induced mortality and habitat changes, and lake sturgeon populations are unable to rebound quickly and may remain depleted for decades (Houston 1987). Lake sturgeon also rely upon specific habitats within rivers for spawning and require specific habitat characteristics (e.g., appropriate flow and temperature) for successful spawning and recruitment, attributes which have been blocked, fragmented or eliminated from many rivers.

Lack of Population Viability

Healthy, self-sustaining lake sturgeon populations have been defined by various researchers as those which contain a minimum of 500 to 1,500 breeding individuals (Hay-Chmielewski and Whelan 1997; Auer 2003; LRBOI 2008; Welsh et al. 2010). These estimates were identified as the minimum number needed to prevent over-harvest and maintain genetic diversity within a population. Although one individual based model for lake sturgeon (Schueller and Hayes 2011) has argued that local populations can be sustainable (only 5% chance of extinction over 250 years) with as few as 80 adults, other simulation studies suggest that target population sizes of 1,000 adults and 1,188 adult females are needed to have respective 95% and 99% probabilities of persistence for 40 generations (Velez-Espino and Koops 2009, 2012). Age structure characteristics of self-sustaining lake sturgeon populations have been defined based on age class representation (20 or more adult year classes) and measureable recruitment of age 0 to age 5 fish (Auer 2003). Additional age structure recommendations for healthy lake sturgeon populations include; 70-year old females and 40-year old males, and significant year classes occurring once every 5 years (Holey et al., 2000).

Auer (2003, p.1) defined a self-sustaining population of lake sturgeon in Lake Superior as one with a minimum of 1,500 mature adults using a common tributary for spawning, a roughly equal sex ratio, 20 or more year-classes of adult fish, evidence of annual reproduction through collection of viable eggs, and measurable recruitment of age 0-5 fish. Not a single lake sturgeon population in Lake Superior, either in the U.S. or in Canada, currently meets those criteria.

The assessment of sustainability of lake sturgeon populations should consider effective population size (Reiman and Allendorf 2001), not just total numbers; a population whose effective population size is too small (< 50) becomes susceptible to inbreeding depression. A population must have enough mature individuals to maintain adaptive genetic variation, assuming a population with equal sex ratios and equal contribution of all adults to the next generation. This has important implications for lake sturgeon, since in many populations sex ratios may be unequal, not all individuals breed every year, and there may be variance in the age of maturity (Earle 2002). Therefore, effective population sizes for lake sturgeon populations may be substantially smaller than total population estimates or censuses (COSEWIC 2006). As fisheries population estimates have substantial uncertainty and risk of extinction is serious and potentially irreversible, precautionary principles suggest adopting the lower 95% confidence limit for a population estimate as the basis for status assessment (COSEWIC 2006). This practice corresponds to recommended practices in fisheries population dynamics as well (Richards and Maguire 1998).

For lake sturgeon, access to a minimum of 250-300 km (and up to 750-1,000 km) of unrestricted habitat, including preferred spawning areas in upper river reaches, lake habitat for feeding and wintering needs, and river mouths for juvenile growth, is needed to ensure long-term survival of minimum viable populations (Auer 1996a, p. 158).

Most researchers agree that to maintain a self-sustaining lake sturgeon population, the maximum mortality rate should not exceed 5 percent; this is calculated based on the rate of recruitment in self-sustaining populations, which is approximately 4.7 to 5.4 percent (Sunde 1961; Priegel 1973; Priegel and Wirth 1975; Baker 1980).

Compromised Genetic Integrity

Active stocking of lake sturgeon is a widely used management tool, originally aimed at maintaining population levels for commercial and recreational harvest, but which can potentially speed the recovery of lake sturgeon populations by reducing the dependency on the slow process of natural recolonization. Stocking programs use eggs, larvae, fingerlings, and occasionally adults (translocation). There is some concern about restoration efforts using out of basin sturgeon for lake stocking programs, to avoid potential negative genetic consequences on both reintroduced and persisting lake sturgeon populations. Drauch and Rhodes (2007) cautioned that lake sturgeon from Lake Winnebago, Wisconsin, which were initially widely used for reintroductions across North America, could potentially homogenize the overall lake sturgeon metapopulation.

Welsh et al. (2010, pp. 4-8) detailed the genetic risks from stocking, which include outbreeding depression and reduced fitness, an inadequate representation of genetic diversity in the captive population or the stocked progeny, and/or artificial selection. Welsh et al. (2010) noted that the genetic consequences of stocking may not be observed readily because of the lake sturgeon’s life history and its relative inaccessibility during non-spawning periods. Since most stocking now occurs at locations where populations have been extirpated, outbreeding depression is a risk where stocking occurs in areas where a native sturgeon population still exists, or from straying of stocked individuals that subsequently breed with remnant spawning populations (Welsh et al. 2010).

Many of the more recent reintroduction and stocking programs by states have stocked fish acquired or raised from the same basin, or utilized streamside rearing facilities to grow fish from sturgeon eggs or larvae collected from within the same watershed. Streamside rearing facilities also improve survival by bringing larval fish collected from the wild into a culture facility for several months before releasing them back into the wild.

Welsh et al. (2010, p. 9) identified appropriate genetic stocking units of lake sturgeon to be used for Great Lakes reintroduction efforts, and outlined conservation stocking principles:

- The genetic structure and diversity of existing healthy natural populations should be preserved.
- Selection of appropriate donor stocks for reintroduction should be based on their likely genetic similarity to neighboring populations.
- The effective population size of lake sturgeon populations, both wild and hatchery produced, should be maximized. Practices such as maximizing the number of parents used for each generation and equalizing family contributions help maximize the effective population size.
- Mating practices should preserve the genetic diversity of the donor population so as to reduce the potential for inbreeding.
- Rearing techniques for propagated fish should promote homing so as to minimize the likelihood of straying by hatchery fish.
- Sturgeon that are released into the wild should represent the natural genetic diversity of the donor population.

In some cases where natural lake sturgeon populations have been extirpated from an entire basin, such as in Alabama and Georgia, it may be appropriate to use out of basin sturgeon for reintroductions.

CRITICAL HABITAT

The Petitioner requests the designation of critical habitat for all U.S. populations of lake sturgeon concurrent with listing. The lake sturgeon has already been extirpated from many areas in its historic range. Critical habitat should encompass all known and potential spawning and rearing areas for endangered or threatened U.S. distinct population segments, as well as wintering areas, major feeding areas and known migratory routes.

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Personal Communications

John Lott, Aquatic Resources Chief, South Dakota Game, Fish and Parks

Amy B. Welsh, Ph.D., Assistant Professor, West Virginia University School of Natural Resources