New York State
Department of Environmental Conservation

Conservation Management Plan for Sauger in New York State 2013 - 2020

Photo by: Emily Zollweg-Horan, NYSDEC 2010

Division of Fish, Wildlife and Marine Resources
Bureau of Fisheries
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Date

Mission of the Bureau of Fisheries

Conserve and enhance New York State's abundant and diverse populations of freshwater fishes while providing the public with quality recreational angling opportunities.

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Acknowledgments

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Executive Summary

Sauger are North American members of the true perch family, Percidae, and closely resemble walleye in both appearance and function. They are highly migratory and typically inhabit large, turbid rivers, lakes, and reservoirs. They were once prominent members of the fish assemblages of the Great Lakes, St. Lawrence River, and Lake Champlain watersheds of New York, but these populations have declined to the point that perhaps only a small remnant population in Lake Champlain still exists. Sauger are now considered critically imperiled in New York State and, therefore, conservation and restoration actions are warranted.

The goal of this plan is to establish and maintain self-sustaining sauger populations in all suitable waters of native watersheds. The number of suitable waters still needs to be determined as some waters where sauger once occurred in New York, such as the upper St. Lawrence River and Lake Ontario, may no longer be able to support sauger populations. Increased water clarity, because of reductions in nutrient loading and the invasion of zebra mussels, and restricted access to potentially important habitats due to dam construction are key factors in the degradation of sauger habitat quality in these areas. Therefore, management efforts will initially focus on the Allegheny River, Lake Champlain, and Lake Erie watersheds. Suitable habitat likely exists in these waters and adjacent viable populations or recovery efforts suggest establishment of populations is achievable.

A sauger population and popular fishery currently exists in the Allegheny River below the Kinzua Dam in Pennsylvania. Conewango Creek, a tributary that enters the Allegheny River below the dam, was recently made accessible to sauger with the removal of a lowhead dam at the mouth. Sauger can now move unobstructed into this portion of the Allegheny watershed in New York. The fish community of Conewango Creek will be monitored to determine if sauger are entering and inhabiting the system. The Allegheny River population is, however, blocked from entering the New York portion of the river due to the Kinzua Dam. The development and implementation of a stocking program is required to establish a population in the reservoir and river section above the dam.

Sauger still presumably occur in Lake Champlain, but because only one fish has been collected during surveys over the last 15 years, this population appears to be at risk of extirpation. However, small numbers of sauger are regularly documented in the lake's outlet, the Richelieu River, and further downstream in the St. Lawrence River, both in Quebec, Canada. Also, there is evidence that sauger are utilizing the recently constructed Vianney-Legendre fishway at the St. Ours Dam on the Richelieu River and moving towards northern Lake Champlain. Management actions will include fish community surveys of northern and southern Lake Champlain, habitat suitability assessments, habitat construction and restoration, and determination of the need and feasibility of a stocking program.

In Lake Erie, sauger were historically most abundant in the western basin, but were numerous enough in the eastern basin to support a commercial fishery in the early 20th

century. The lakewide population crashed in the 1950's and is now extirpated. The Ohio Department of Natural Resources is currently developing a restoration program for sauger in western Lake Erie and this could have implications for the eastern basin if sauger become established and migrate east. The suitability of New York's Lake Erie tributaries will be assessed for potential sauger restoration.

The goal of this plan is to be achieved by 2030. Actions in this plan will be implemented through 2020. Progress made towards completing these actions and meeting objectives will serve as guidance in the development of new objectives and management recommendations for the period 2021 – 2030.

Introduction

Sauger (*Sander canadensis*) are one of the most widely distributed fishes in North America, but have declined in abundance and distribution throughout large portions of their range, particularly at the periphery (Rawson and Scholl 1978, Hesse 1994, Pegg et al. 1997). In New York, at the northeastern edge of its range, its recorded historic distribution included the Lake Erie, Lake Ontario, St. Lawrence River and Lake Champlain drainage basins. Sauger have been extirpated from all of these watersheds, except Lake Champlain (Carlson 2006, NYSDEC 2006a), but the status of this population is in doubt as only one sauger has been captured (in 2010) as part of a sampling program in approximately 15 years. Sauger also are native to the Allegheny River, but were extirpated there due to severe pollution in the late 19th and much of the 20th centuries (Koryak et al. 2009). There are no historic records of sauger in the New York portion of the Allegheny watershed, but they likely occurred there before the degradation of the river. Sauger have recently returned to the lower Pennsylvania section of the Allegheny River, but access to the New York portion of the river is blocked by the Kinzua Dam. Sauger are currently listed as a species of greatest conservation need in New York State with a rank of S1, indicating that it is considered critically imperiled (NYSDEC 2006). Sauger have therefore been identified by the NYSDEC Bureau of Fisheries as a priority species for conservation management.

This document provides the requisite background information and a systematic approach of actions towards the goal of sauger conservation and management in New York State. Recovery would include establishing and maintaining secure self-sustaining populations of sauger in all suitable waters of native watersheds by 2030. Sauger conservation is dependent on a comprehensive suite of actions including identification of suitable waters, habitat assessments and restoration, fish community assessments, development and implementation of propagation and stocking programs, public outreach, protective regulations, and follow-up monitoring.

Natural History

Physical description and taxonomic status

Sauger belong to the order Perciformes which is the largest order of vertebrate fishes and includes about 40% of all bony fish. Sauger are one of the largest members of the family Percidae (includes the true perches: darters, perches and pike-perches) and are similar to the closely related walleye (*Sander vitreus*) both in appearance (Figure 1) and habits (Appendix 1). Both have large canine teeth and an elongate and cylindrical body shape; however, sauger lack the dark spot found on the bottom of the walleye's first dorsal fin and the white edge on the lower caudal lobe (Smith 1985, Werner 2004). In addition, sauger uniquely have three to four saddle-shaped dark brown blotches on light brown to olive-colored sides and distinct black spots on the first dorsal fin. While sauger do not grow as large as walleye, averaging 10 – 18 inches, they occasionally reach 20 inches in length or more (Mammoliti 2007).

Figure 1. Sauger (top) and walleye (images by Ellen Edmonson, New York Biological Survey).

Geographic range

Sauger are widely distributed across eastern and central North America. Their historical range included the St. Lawrence River, Great Lakes, Hudson Bay, and Mississippi River basins from Quebec to Alberta and south to northern Louisiana (Figure 2). It was introduced to several gulf and Atlantic coast drainages (Smith 1985, Page and Burr 1991). However, the once thriving Lake Erie population is now extirpated and there is recent evidence that sauger are declining in abundance or disappearing from other portions of their range, especially at the periphery (Rawson and Scholl 1978, Pegg et al. 1997, Leonardi and Thomas 2000, McMahon and Gardner 2001, Environment Canada and USEPA 2006). Despite this, populations do still exist in the lower Saint Lawrence River drainage (Osterberg 1978, Reyjol et al. 2010, Thiem et al. 2012) and in Lake Winnebago in the upper Great Lakes drainage (Wisconsin DNR 2005).

In New York, sauger were known to inhabit the Lake Erie, Lake Ontario, Oswego River, St. Lawrence River and Lake Champlain watersheds (Carlson 2006, Figure 3), but the Great Lakes/Oswego/St. Lawrence watershed populations are now extirpated (Carlson 2006, Environment Canada and USEPA 2006). The Lake Champlain population may be the last known viable population in New York; however, a fortuitous catch of one female sauger[1] in 2010 is the only direct evidence of their existence there in the last 15 years. Sauger have recently been documented in Lake Champlain's outlet, the Richelieu River in Quebec, Canada, where they are utilizing the recently constructed (2001) Vianney-Legendre fishway at the Saint Ours Dam and moving upriver in the direction of the lake (Thiem 2012). Sauger occur in the Allegheny River watershed and a popular fishery exists in the lower Pennsylvania section from the mouth in Pittsburgh to Lock and Dam 9, approximately 60 miles upstream. Sauger have been recorded as far north as Warren, Pennsylvania (Fowler 1919), but there are no records in any portion of the drainage in New York.

[1] Confirmed via genetic analysis by Dr. Carol Stepien, University of Toledo

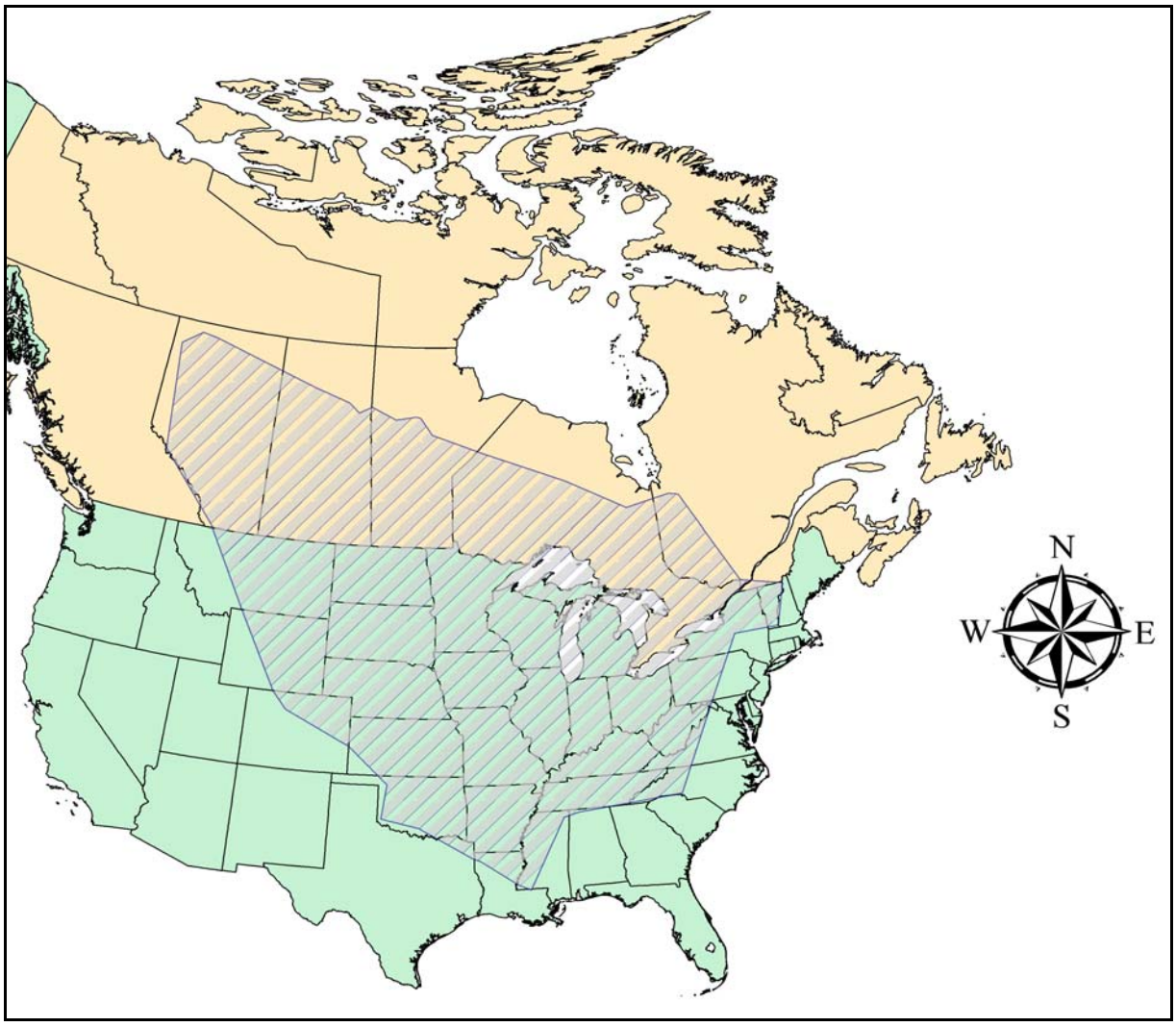

Figure 2. Native range of sauger.

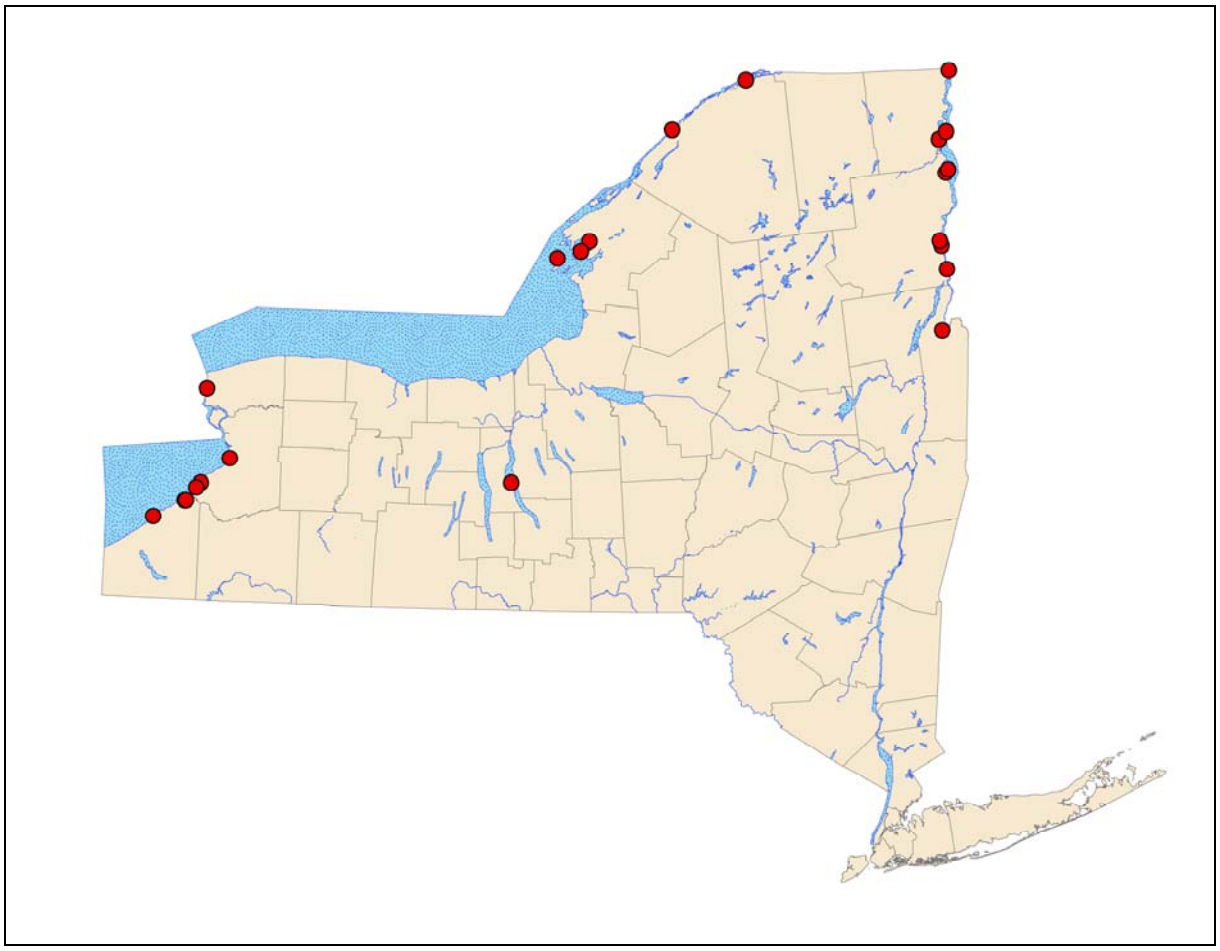

Figure 3. Historic collection locations of sauger in New York, 1884 – 1990 (NYSDEC fish atlas database).

Breeding biology and development

Sauger typically reach reproductive maturity at 2 to 4 years of age (Pitlo et al. 2004), with females maturing later than males. During late winter adult sauger begin to migrate to spawning locations. Sauger are highly selective of spawning sites and long distance movements are sometimes necessary for the species to reach preferred locations. For example, Clay (1975) documented spawning-related movement of 236 miles in the Tennessee River. Because of this, sauger are considered the most migratory percid (Collette et al. 1977, Pegg et al. 1997). Spawning does occur in lake shore and mainstem river locations (Jaeger et al. 2005), but there is evidence to suggest that sauger populations are reliant on the availability of spawning habitats associated with large tributaries (Penkal 1992, Hesse 1994). Sauger typically spawn at night (Hesse 1994) over a gravel/cobble substrate, but may utilize sand, boulders and bedrock (Crance 1987). Flowing water is a key requirement and velocities between 3.6 and 24 in/s are considered ideal (Crance 1987). Turbidity is also thought to be an important spawning habitat characteristic and is likely a factor in selection of spawning locations (Doan 1941).

Spawning commences when water temperatures reach about 43 - 55º F and can last for 2 weeks or more (Nelson 1968, Pitlo 1992, Etnier and Starnes 1993). Males are first to arrive at spawning sites and are soon followed by females (Nelson 1968). Spawning occurs in small groups (as opposed to walleye, which spawn in large aggregations), with several males attending each female (Boshung and Mayden 2004, Seigwarth et al. 1993). Most spawning activity occurs at night, particularly during the first two hours after sunset (Nelson 1968). Females deposit 9,000 to 200,000 eggs, depending on size of fish (Etnier and Starnes 1993, Rohde et al. 1994, Ross 2001), and leave the area soon after spawning. No parental care is provided and eggs hatch in 1 to 4 weeks (Nelson 1968, Smith 2002), depending on water temperature; the higher the water temperature, the sooner the eggs will hatch (Pitlo et al. 2004).

Walleye typically spawn earlier than sauger (at water temperatures between 35 - 46º F, Smith 1985, Roseman et al. 2002), but spawning may overlap and natural hybrids do occur. Consistent low-level hybridization (4 – 21% of the total combined walleye and sauger populations) has been reported in Missouri River reservoirs and this may be due to limited spawning habitats, forcing the species to use the same areas (Walburg 1972, Ward 1992, Graeb 2006).

Sauger eggs are initially adhesive and stick to firm substrate; gradually becoming non-adhesive and buoyant as they water harden. During a 10-12 day period following emergence, larval sauger in riverine systems may drift long distances downstream prior to gaining the ability to move horizontally and begin feeding (Nelson 1968, Pankal 1992, McMahon 1999). Juveniles typically inhabit side channels, backwaters, oxbows, and other off-channel habitats during spring and summer before shifting to main channel habitats in autumn (Gardner and Berg 1980, Gardner and Stewart 1987, Hesse 1994). During larval and early juvenile stages, sauger feed on zooplankton and benthic invertebrates before shifting to a diet of primarily fish by the autumn of their first year (Nelson 1968, Swenson and Smith 1976, Gardner and Stewart 1987). Sauger year class strength is typically set by the autumn of their first year and is thought to be influenced most strongly by water temperature and volume and fluctuation of streamflow (Nelson 1968, Walburg 1972, Koonce et al. 1977, McMahon and Gardner 2001).

Young sauger grow rapidly, attaining half their maximum adult size in 2 years. Growth is positively related to water temperature and is typically faster in reservoirs versus rivers. Southern sauger grow faster than those in the north, but northern sauger tend to live longer and can attain the same ultimate size as their southern counterparts (Scott and Crossman 1998, Boshung and Mayden 2004). The average lifespan of sauger is about 7 years (Preigel 1969, Gebkin and Wright 1972), but this varies by location. Thirteen year old sauger were captured in Wyoming (Krueger et al. 1997), whereas a multi-year study in the Ohio River failed to document sauger over 4 years old (Schell et al. 2004).

Non-breeding biology

Habitat use

Sauger typically occur in large turbid rivers and lakes (Becker 1983). The highly migratory nature of sauger reflects their dependence on unimpeded access to the wide diversity of physical habitats that are present in large river and lake systems. Adult sauger in riverine systems tend to use off-channel and channel margin habitats during the spring and early summer periods of high flow and turbidity, and then move to deeper main channel habitats in late summer and autumn as decreasing flows and turbidities cause off-channel sites to become unsuitable (Hesse 1994). Physiological adaptations, such as a highly advanced light-gathering retina, allow sauger to thrive in low light environments, and thus turbidity is considered a key component of suitable habitat (Crance 1987). Other important riverine habitat features include low channel slope and deep, low-velocity pools (Crance 1987, Hesse 1994, Bellgraph 2006). Deep pools provide both a low velocity refuge and cover during high light conditions. Use of structure has been documented in some locations (Kitchell 1977, Bellgraph 2006), and this behavior may be related to a reduction in water velocity behind cover (Mammoliti 2007). Diverse, natural river channels are preferred over relatively simple, uniform channelized segments (Groen and Schmulbach 1978, Seigwarth et al. 1993, Hesse 1994). River impoundments and lakes can be seasonally important as overwintering and pre- and post spawning habitats (Nelson 1968, Holland 1985, Pitlo 1985, Pitlo 1992). In large lakes and reservoirs, sauger may depend on lentic habitats year-round, only using tributaries during spawning (Ickes et al. 1999).

Movement

Sauger are the most migratory percid in North America (Collette et al. 1977) and have been found to move great distances in large river systems (Pegg et al. 1997, Jaeger et al. 2005). These long migrations are most often linked to the need to find suitable spawning habitats and the return trip to non-spawning “home” locations (Mammoliti 2007). For example, sauger in the Missouri and Yellowstone rivers both migrated considerable distances downstream (up to 152 miles in the Missouri and 186 miles in the Yellowstone River) to spawn and then returned back upstream (Jaeger et al. 2005, Bellgraph 2006). However, other studies have documented much smaller migrations (Siegwarth et al. 1993, Schell et al. 2004) and movements appear to be dependent of the availability of suitable spawning habitats near “home” locations and the presence of dams, which obviously could impede the species ability to migrate.

Food habits

Sauger are top trophic level predators for most of their lives (Collette et al. 1977, Nelson and Walburg 1977) and are opportunistic piscivores, generally feeding on a wide variety of fish in proportion to their relative abundance (Elser et al. 1977, Swenson 1977, Preigel 1983, Mero 1992). However, during times of low prey fish abundance, benthic invertebrates make up part of the diet (Preigel 1963, Swenson and Smith 1977). Sauger are visual predators, but are highly light sensitive and most effective in low-light conditions (Collette et al. 1977). Their feeding activity tends to occur crepuscularly, with movement from offshore resting locations in the day to inshore feeding areas at dusk and

dawn (Carlander and Cleary 1949, Swenson 1977, Welker 2002). Sauger may feed throughout the day in highly turbid water (Ali and Anctil 1977).

Larval sauger typically feed on large zooplankton (cladocerans and copepods) and aquatic insects (Nelson 1968, Scott and Crossman 1998, Boshung and Mayden 2004). Commonly reported prey items for adult sauger include emerald shiners (*Notropis atherinoides*), gizzard shad (*Dorosoma cepedianum*), freshwater drum (*Aplodinotus grunniens*), and various centrarchids (Mammoliti 2007). Sauger in Lake St. Pierre of the St. Lawrence River were more likely to consume round gobies (*Neogobius melanostomus*) than any other species (Reyjol et al. 2010).

Historical Status Assessment

Sauger were never ubiquitous in New York, occurring only in the Great Lakes and connecting waters, including the St. Lawrence River, and Lake Champlain. In Lake Erie, sauger were most abundant in the turbid, shallow western basin (Doan 1941); they were, however, numerous enough in the eastern waters to support a sporadic New York-based commercial fishery from around the turn of the 20th century up until the late 1930's. The overall Lake Erie commercial sauger catch outnumbered the walleye catch until the 1930's, and began a downward trend until the mid-1950's, when the fishery, and subsequently the entire population, collapsed. By the early 1970's speculation arose that the population was nearing extirpation (Applegate and Van Meter 1970). The Ohio Department of Natural Resources began a stocking program in 1974 to re-establish the western basin population; however, stocked sauger failed to reproduce and the effort was not successful (Rawson and Scholl 1978).

Certain areas of Lake Ontario also harbored abundant sauger populations (Burlington and Toronto bays in Ontario, Canada) in the late 1800's, but these populations declined by the turn of the 20th century (Goodyear et al. 1982). Several early records (1894 and 1942) exist in the Chaumont Bay area of the eastern section of the lake. The last New York record from the upper St. Lawrence River was from below Massena in 1933.

Sauger were also considered relatively common in Lake Champlain as recently as the mid-1980's (Smith 1985). However, this population apparently declined to the point where it eluded detection by New York and Vermont fisheries biologists from 1994 (Nettles et al. 2005) until 2010.

Historically, sauger were found in the Allegheny River as far north as Warren Pennsylvania (Fowler 1919), but there are no sauger records in any portion of the New York drainage. However, this does not mean that sauger never occurred there, as pollution levels of the late 19th and much of the 20th centuries led to the depletion, and sometimes extirpation, of many fish species, particularly those associated with large river habitats such as sauger, paddlefish (*Polyodon spathula*), and lake sturgeon (*Acipenser fulvenscens*) (Eaton et al. 1982, Koryak et al. 2009). It is therefore not surprising that these species are rare or absent from fish surveys of the upper river throughout the early and mid-20th century (Carlson et al. 1999). Despite improvements to water quality and a

resulting resurgence of the native fish community in the lower Pennsylvania section, the river is still considered to be in a state of recovery (Koryak et al. 2009). Confounding fish community recovery was the construction of the Kinzua Dam at Warren, Pennsylvania in 1966, which became a barrier that prevented reestablishment of several species, including sauger, otherwise capable of returning upstream.

There is also an historic record of a sauger in Cayuga Lake. This fish was thought to be associated with a population in the Seneca River, although no specimens were ever collected there (Meek 1889, Greeley 1928).

Current Status Assessment

Population status and distribution

Sauger are one of the most widely distributed percids in North America (Figure 2), but recently researchers have documented population declines in both distribution and abundance, particularly at the periphery of its range. Regionally, the once thriving Lake Erie population is now considered to be extirpated (Environment Canada and USEPA 2006) and declines have also been documented in the upper Missouri River Basin (McMahon and Gardner 2001, Mammoliti 2007). Population recovery efforts are occurring in Lake Winnebago, WI (Wisconsin DNR 2005). The most proximal sauger populations to New York State are those in the Ottawa River, Ontario (Osterberg 1978), Lake Saint Pierre - Saint Lawrence River, and Richelieu River, Quebec (Reyjol et al. 2010, Thiem et al. 2012) and the Allegheny River, Pennsylvania (Lorantas et al. 2005). These populations appear to be stable.

The scarcity of recent evidence of sauger in New York waters suggests that the species has been extirpated from its historic range in the state, except Lake Champlain. Before the surprising find of a female sauger in South Bay of Lake Champlain during spring 2010 walleye brood stock collections, the last sauger recorded from a New York water was from Lake Champlain in 1994 (Nettles et al. 2005) and the last sauger documented from another water was an angler caught fish in 1990 from the lower Niagara River (this is the state record sauger). The Lake Champlain population was considered the last viable population in the state and sauger were collected in considerable numbers during surveys in the mid-1980's (Fisheries Technical Committee 2009). Sauger were once present throughout the lake, except the Main Lake, but were more abundant in the shallow, more turbid southern sections (Halnon 1963, Anderson 1978). Reasons for the decline of this population are unknown, but may include declining habitat quality, competition or introgression with walleye, or changes in the fish community of the lake. There is recent evidence to suggest that sauger may be moving from the Richelieu River to northern Lake Champlain through the Vianney-Legendre fishway at the St. Ours Dam (Thiem et al. 2012). This fishway was constructed in 2001 and sauger have been documented in small numbers moving upriver through the fishway every year from late May to late June (Pierre Dumont, Quebec Ministry of Natural Resources, personal communication, e-mail 4/4/12). Comprehensive fish population surveys of northern Lake Champlain (Rouse's Point/Great Chazy River/Kings Bay area) have not been conducted by DEC since the

mid-1980's, therefore the implications of sauger moving through the fishway are currently unknown.

In the Allegheny River watershed, a lowhead dam at the mouth of the Conewango Creek in Warren, PA was removed in 2009. This provided Allegheny River sauger access to the creek, thus extending their potential range into New York. Sauger in the main stem of the Allegheny River are currently blocked from entering the New York portion of the river by the Kinzua Dam.

Threats to Species

Sauger are highly migratory, spawn in specialized areas, and rely on a diverse mix of habitats with high turbidities, flowing waters and natural temperatures throughout their lifespan. They have evolved to benefit from the continuity and complexity of large river and lake systems (Mammoliti 2007). These characteristics make sauger highly sensitive to habitat fragmentation and alterations. Migration barriers, operation of impoundments, low water flows, channelization, degradation of spawning habitats, increasing water clarity, and pollution have all been implicated as causes of sauger population declines (Regier et al. 1969, Rawson and Scholl 1978, Hesse 1994, Pegg et al. 1997, McMahon and Gardner 2001, Jaeger et al. 2005, Carlson 2006).

In certain waters where sauger are vulnerable to heavy angling pressure, over-exploitation has been implicated in population declines (Nelson 1969, Hesse 1994, Pegg et al. 1996). Seasonal aggregations in discreet spawning areas and crowding of migrating fish behind dams might lead to overexploitation in some areas (Penkal 1992, Nelson 1969, Hesse 1994, Pegg et al. 1996). Ryan et al. (2003) speculated that commercial fishing pressure, combined with relatively slow growth rates, late sexual maturity, degraded spawning reefs, and restricted access to rivers, contributed to the collapse of the Lake Erie sauger population.

In waters where there are concurrent sauger and walleye populations, peak spawning activity can overlap and hybridization does occur (Stroud 1948, Billington et al. 2004). This may be more pronounced in highly altered river systems, with barriers, narrowed flood plains, and unnatural flow patterns that diminish specialized habitats. Graeb (2006) found that natural hybridization rates ranged from 4% - 21% in three Missouri River reservoirs. Multiple year classes of hybrids were reported in each reservoir, indicating consistent low-level recruitment. Such introgressive hybridization between these species may be a limiting factor in their ability to naturally sustain viable populations by masking traits that would allow for the most advantageous use of native habitats.

Increasing water temperatures and more extreme weather events brought on by a warming climate may threaten sauger populations. Warming water temperatures may directly affect the suitability of certain waters for sauger, especially at the northern and southern edges of their range, due to inherent thermal tolerances of the species. Climate change may also lead to changes in existing fish communities, which may or may not

benefit sauger. For example, increasing water temperatures in Lake Champlain would favor warm water invasives such as alewives (*Alosa pseudoharengus*) and white perch (*Morone americana*), which may impair successful sauger reproduction due to egg predation, but could benefit condition and growth rates of adult sauger because of their contribution to the forage base. An increase in extreme weather events, such as prolonged periods of drought or more severe precipitation may impact all sauger life stages, particularly larval and early juvenile stages that depend on relatively stable water conditions (Nelson 1968, Walburg 1972, Koonce et al. 1977, McMahon and Gardner 2001).

Data Gaps

Sauger are relatively well-studied and much is known about their population biology and ecological requirements. In general, there are no significant gaps in our knowledge of sauger that would preclude making appropriate management decisions for species conservation and restoration. However, for specific populations and potential restoration waters in New York, data needs exist (e.g., status of current population, habitat suitability, fish community composition, etc.), but these needs are addressed on a case by case basis as part of the conservation plan process.

Confidence Level

Sauger were once an important commercial species and are currently a popular sportfish throughout most of their range. Because of this, they are a common subject of research and management, and thus the scientific literature on sauger is relatively comprehensive. There is a high degree of certainty about the life history, status, and distribution of the species. There is less certainty about some of the threats, such as introgression with walleye, impacts of climate change, or competition with other species.

Current Conservation Efforts

Fishing Regulations

The sauger is perhaps New York's most imperiled fish species. There is only one known location where it currently exists, and the status of that population is unknown; but because of the scarcity of recent records it is likely at risk of extirpation. The current statewide fishing regulation for sauger is "any size, any number, no closed season" which, of course, is not protective and does not reflect either its traditional status as a sportfish or its current situation as a species at risk. In 2008, a harvest regulation change for Lake Champlain was made to "3 sauger or walleye (combined)/day and a minimum length of 18 inches", in part, to severely restrict the potential harvest of sauger while maintaining the ability to harvest larger walleye. The 2009 Strategic Plan for Lake Champlain Fisheries (Fisheries Technical Committee 2009) states that sauger have "attracted little attention in Lake Champlain", but the regulation change "virtually eliminate(s) potential angler harvest of sauger". However, the female sauger captured from South Bay in 2010 was almost 20 inches in length and could have legally been

harvested by an angler. The Strategic Plan for Lake Champlain Fisheries only provides generic management goals for species of greatest conservation need, with no specific plan, goals or information needs for sauger.

With the implementation of sauger conservation efforts in Lake Erie and the Allegheny River, dam removal on Conewango Creek, and the occasional anecdotal angler reports of sauger in Lake Erie and the lower Niagara River (M. Clancy, NYSDEC Region 9 Fisheries Manager, personal communication) it is imperative that protective statewide harvest restrictions are adopted. In 2013, a proposal to change the statewide regulation to prohibit take and possession of sauger was developed. If approved, this regulation change would take effect in 2014. It is also the intention of NYSDEC Bureau of Fisheries to include Lake Champlain with the proposed statewide regulation; however, because of inter-jurisdictional concerns this will be discussed with members of the Lake Champlain Policy and Technical committees before implementation.

Restoration Planning

Other than the 2008 harvest regulation change for Lake Champlain, there had been no directed sauger management activities in New York State from the mid-1990's through 2010. On February 17, 2011 the Sauger Management Team (see page 4) convened to discuss sauger management goals and strategies. The team identified four waters as candidates for sauger population management: Lake Champlain, Black River, Genesee River and Allegheny River. Other parts of the historic range, including Lake Ontario, Lake Erie and the St. Lawrence River, were ruled out for future management because the habitats were no longer deemed suitable for sauger due primarily to increased water clarity (Binding et al. 2007). Further discussions with NYSDEC Regional and Central Office (Albany) Fisheries staff led to a decision to focus initial management efforts in Lake Champlain and the Allegheny River and to provide further consideration towards the potential of the eastern basin of Lake Erie. The decision to remove the Genesee and Black rivers from management consideration was based on 1) the potential difficulties associated with identifying and procuring an appropriate brood stock for the Genesee and Black Rivers, and 2) unknown fish community and fishery conflicts, particularly concerning walleye, with the introduction of sauger in these two systems. These waters may be reconsidered for sauger management in the future if these issues are addressed. Another water that may be considered for future sauger management is the Seneca River, which, despite a lack of specimen records, was considered a likely sauger water, and could have been the source of the Cayuga Lake specimen collected in the late 1800's (Greeley 1928).

The Ohio DNR is currently developing a plan to restore sauger in the western basin of Lake Erie. While full details of the plan are not yet known, initial efforts will be focused on finding the most appropriate broodstock (J. Tyson, Ohio DNR, personal communication, e-mail 10/20/2010). Re-establishment of the western Lake Erie population could have implications for the eastern basin of the lake. The current suitability of the eastern basin for sauger is unknown, but some tributaries, such as Cattaraugus and Tonawanda creeks, are large and turbid, and thus may have potential.

Monitoring

In April 2011, NYSDEC Region 5 Fisheries personnel conducted boat electrofishing and trap netting surveys targeting spawning sauger in South Bay Lake Champlain. This was the first targeted sauger survey by NYSDEC Fisheries since the mid-1980s. Unfortunately, surveys were limited due to severe rainfall and flooding and no sauger were captured. In 2012, NYSDEC Region 5 Fisheries staff also conducted a boat electrofishing survey of the lower Great Chazy River, a northern Lake Champlain tributary. Again, sauger were not captured.

Conservation Management Strategy

Goal

Establish and maintain secure self-sustaining sauger populations in all suitable waters of native watersheds by 2030.

For the purposes of this plan, a self-sustaining population is one where at least 3 naturally produced year classes are present in a population. Achievement of this goal is expected to result in the establishment of sauger fishing opportunities in each water.

Units

Initial conservation actions will take place within 3 distinct watersheds: Allegheny River, Lake Champlain, and Lake Erie.

Objectives

These objectives are designed to be implemented through 2020. Progress made towards meeting these objectives will serve as guidance in the development of new objectives and management recommendations for the period 2021 – 2030. Additional waters will be considered for sauger population establishment during this time.

1. Establish a self-sustaining sauger population in the upper Allegheny River watershed.

2. Determine sauger population status and document and improve habitat suitability in Lake Champlain.

3. Determine the suitability of Lake Erie's eastern basin watershed for sauger restoration.

Actions

Management

Allegheny River watershed

1. Develop and implement a stocking program for the Allegheny River watershed above the Kinzua Dam.

   Justification for stocking: Sauger thrive in the lower Allegheny River but are blocked from the upper New York portion of the river by the Kinzua Dam. Therefore, the restoration of this species to the New York waters of the Allegheny River is dependent on implementation of a stocking program.

   a. Identify an appropriate Ohio River strain brood stock source and develop a propagation program or another means of acquiring sauger for stocking. West Virginia hatchery staff have offered Ohio River strain sauger fry/fingerlings to New York in the recent past (M. Clancy, NYSDEC Region 9 Fisheries Manager, personal communication) and this option will be assessed for the Allegheny River. The feasibility of using one of the NYSDEC coolwater hatcheries or other facilities for raising sauger fingerlings will also be examined. Any stocking must be consistent with NYSDEC fish health inspection regulations as specified in NYCRR Title 6, Part 188.1 and 188.2.

   b. Implement an experimental 5 year stocking program based on DEC guidelines for walleye restoration (Festa et al. 1987). A pre-stocking fish community and habitat survey will be completed in 2013. Stocking will commence in 2014 and will be conducted annually until 2018. Sections of the Allegheny River watershed deemed appropriate for young of year survival will be selected for stocking. Selected sections will be stocked with sauger fingerlings at the rate of 20/acre or fry at the rate of 3,000/acre, which are the standard rates used by NYSDEC for walleye stocking in ponded waters. Stocking rates that may be more appropriate for riverine systems are currently unknown, but adjustments to stocking rates will be made if this information becomes available.

Lake Champlain

1. Determine the need and feasibility of a stocking program for Lake Champlain.

   a. The necessity of establishing a propagation or transfer program for stocking certain areas of the lake will be based on the results of the population and habitat assessments. If relative population estimates based on electrofishing and/or netting are observed to be marginal or less (as described in the NYSDEC Percid Sampling Manual, Forney et al. 1994)

and habitat and fish community composition are determined to be suitable, then a stocking program may be recommended for population restoration.

b. Identify an appropriate brood or transfer source. Populations in Lake Champlain, Lake St. Pierre, and the Ottawa and Richelieu rivers will be assessed for their potential. Genetic suitability will be a key consideration. The Ohio DNR is currently conducting a genetic assessment of Great Lakes basin and other populations (J. Tyson, Ohio DNR, personal communication, e-mail 10/20/2010) that may be useful for determining appropriate brood stocks.

c. Identify a potential propagation facility for raising sauger fry and/or fingerlings.

d. Decisions to establish and conduct a stocking program for Lake Champlain will be made in consultation with the agencies in the Lake Champlain Fish and Wildlife Cooperative (Vermont Department of Fish and Wildlife and USFWS) and the Quebec Ministry of Natural Resources.

e. If deemed necessary and feasible, develop a 5-year stocking program based on NYSDEC guidelines for walleye restoration (Festa et al. 1987).

2. Identify, protect and enhance important habitats.

a. Identify actual and potential spawning sites during population monitoring activities and habitat suitability assessments. Use spawning site characteristics to develop spawning habitat restoration plans.

b. Develop and provide specific information on important sauger habitats (e.g., locations and physical characteristics) to NYSDEC staff involved in permit reviews.

c. Determine, develop, and implement habitat improvement projects. This may include the construction of stone reefs in Lake Champlain to improve spawning habitat in the lake, which has been successfully done for sauger in Lake Winnebago, WI. Fish passage, including dam removal, will also be a primary consideration in assessing habitat improvements.

Monitoring

Allegheny River watershed

1. Monitor Conewango Creek for potential immigration of sauger from the Allegheny River in Pennsylvania.

a. Conduct a sauger population survey in the Conewango Creek watershed to determine if sauger have entered the watershed following removal of the lowhead dam at the creek's mouth in Warren, Pennsylvania in 2009.

2. Monitor the status of the stocking program in the Allegheny River watershed.

a. Conduct annual surveys for young of year sauger in the fall of each year of stocking.

b. Annually check for spawning aggregations of sauger starting in the 4th year following the initial stocking (2017).

c. Conduct a sauger population survey of the watershed in 2020 using the methods designed for introduced walleye populations in the NYSDEC Percid Sampling Manual (Forney et al. 1994), where feasible.

d. Stocking success will be determined by survival of 2 or more year classes of stocked fish to Age 3 or more and the development of spawning aggregations of sauger.

e. To meet the objective, a self-sustaining population must develop from the stocking program. Annual young of year and spawning surveys and the full population assessment will provide the data necessary to determine if the objective is met by 2020.

Lake Champlain

1. Develop and implement a population monitoring plan to determine the status of sauger in Lake Champlain.

a. Those areas in the Lake Champlain watershed deemed most suitable for sauger will be selected as the principal locations for monitoring. In the north end of the lake this will include the area from Rouses Point to Monty Bay, with an emphasis on King Bay and the Great Chazy River. To the south, South Lake, South Bay and the Poultney River will be monitored.

b. A sampling plan for selected areas will be developed using methods outlined in the NYSDEC Percid Sampling Manual (Forney et al. 1994). Recommended survey methods are those for Management Goal #2: *Increase catch per unit effort in a marginal fishery*. This may include larval surveys using tows or shoreline seining for young of year sauger. Potential spawning sites will also be identified and sampled for the presence of spawning aggregations.

c. Conduct creel surveys of the north and south ends of the lake, in areas selected for population monitoring.

i. The surveys will be designed to capture angler perspectives on historical sauger distribution and abundance.

Lake Erie

1. Continue annual warmwater fish stock assessments in Lake Erie.

    a. Continue to conduct long term annual warmwater gill net, trawl, and angler surveys in the eastern basin. These surveys are designed to capture percids and are therefore appropriate tools for detecting the presence of sauger if they are present in the basin.

    b. Cooperate with other Lake Erie jurisdictions in *Percid* management activities.

        i. Continue to coordinate with the Ohio DNR and other Lake Erie jurisdictions through existing forums (Great Lakes Fishery Commission - Lake Erie Committee) to explore the potential for sauger restoration in Lake Erie. Any actions will be pursued through consensus of the Lake Erie Committee.

Research

Lake Champlain

1. Determine the habitat suitability of Lake Champlain and its tributaries.

    a. Identify important sauger habitat variables, primarily through literature review, and incorporate into a habitat suitability model. Consider draft habitat suitability curves developed for sauger by Crance (1987) for model development. Assess habitat quality by measuring model variables through a combination of GIS evaluations and field surveys and incorporate these measures into model indices. Determination of current habitat suitability will allow for an objective assessment of habitat deficiencies, which will be critical when determining appropriate restoration actions.

    b. Assess sauger distribution, movements, food habits, habitat use and interactions with walleye in Lake Champlain.

        ii. The scope of this study will be contingent on the results of the population monitoring and creel surveys. Use study results to assist development of a comprehensive sauger management strategy for Lake Champlain.

2. Assess the habitat suitability of eastern basin Lake Erie tributaries.

a. Use the draft habitat suitability criteria developed for sauger by Crance (1987) to assess habitat quality of the watershed. Assessments will be made by measuring model variables through a combination of GIS evaluations, currently available data and field surveys, and incorporating these measures into model indices. The suitability of tributaries for spawning will be a part of the assessment.

Outreach

1. Develop a fact sheet on sauger.

a. The fact sheet will provide information on the differences and similarities between sauger and walleye to allow for the correct identification of these two species. The fact sheet will be posted on the NYSDEC public website and at public access sites on the Allegheny River, Lake Champlain, and Lake Erie.

2. Ongoing program activities will be communicated through website updates and distribution of fact sheets at outdoor/sportsmen's shows and exhibitions.

3. Include information in the Freshwater Fishing Regulations Guide to help anglers properly identify sauger.

4. Via the fact sheet, information in the Freshwater Fishing Regulations Guide, and other outreach materials, encourage anglers to report incidental sauger catches to Central Office and Regional Fisheries Units.

Implementation

Actions

Conservation tasks will be conducted and/or coordinated primarily by NYSDEC with assistance from partners on specific tasks. However, successfully addressing plan objectives will require additional staff and funding beyond that which is currently available.

NYSDEC Region 5 Fisheries staff will conduct and coordinate tasks for Lake Champlain. Initial sauger population monitoring will be conducted in collaboration with SUNY Plattsburgh. Additional work, such as habitat assessments and restoration, creel surveys, and research on sauger ecology, will necessitate a comprehensive, focused effort that will require staff and funding beyond what currently exists in the Region 5 Fisheries Unit.

NYSDEC Region 9 Fisheries staff will conduct and coordinate tasks for the Allegheny watershed. Propagation options will be determined in 2013 and additional needs for that

program (e.g., specialized feed, water temperature controls, etc.) will be determined then. Additional funding for hatchery operations may be necessary. Stocking decisions will be made in consultation with the Pennsylvania Fish and Boat Commission and the Seneca Nation. Follow-up monitoring in the Allegheny River and Conewango Creek will require staff and funding beyond what currently exists in the Region 9 Fisheries Unit.

The NYSDEC Lake Erie Fisheries and Region 9 Fisheries units will conduct and coordinate tasks for the Lake Erie watershed. Habitat suitability assessments of Lake Erie tributaries will require additional staff for the Region 9 Fisheries Unit. Lake Erie's core warmwater monitoring programs and cooperation in fisheries management activities through Great Lakes Fishery Commission forums will continue to have a *Percid* focus, and address sauger as needed. This work is a normal part of existing programs, therefore current staffing and funding is adequate to conduct this work.

The NYSDEC Warmwater Fisheries Unit Leader will provide oversight and direction on all aspects of this plan and will assist Regional Fisheries Units with project administration.

Some tasks are dependent on the results of other actions (e.g., a decision to stock Lake Champlain will be based on population/habitat assessments and discussions with the Lake Champlain Fisheries Technical Committee) and thus this plan is intended to be adaptive to this progress and should be adjusted as necessary. In 2020, overall progress towards meeting the objectives of this plan will be evaluated and new objectives and management recommendations will be developed.

Funding Options

The sauger's status as both a sportfish and a species of greatest conservation need makes it somewhat uniquely eligible for funding under both the Federal Aid in Sportfish Restoration and State Wildlife Grant programs. Funding for sauger conservation projects in Lake Champlain may also come from the impending mitigation settlement for in-lake installation of the Champlain-Hudson Power Express powerline (Champlain Hudson Environmental Research and Development Trust). Population monitoring, habitat assessments and restoration, creel surveys, and research on sauger ecology are all tasks that are eligible for funding from the Champlain Hudson Environmental Research and Development Trust.

Timeline

2013:

Complete fish community and habitat survey in the Allegheny River watershed;
Determine propagation options for Allegheny River watershed stocking program that are consistent with NYSDEC fish health inspection regulations;
Develop stocking plan for Allegheny River watershed;
Develop sauger fact sheets for NYSDEC website;
Conduct warmwater fish surveys in Lake Erie;

Propose and review statewide fishing regulation change;

2014:

If feasible, initiate Allegheny River watershed stocking program;
Conduct fall surveys for young of year sauger in the Allegheny River watershed;
Assess habitat suitability of eastern basin Lake Erie watershed;
Conduct warmwater fish surveys in Lake Erie;
Implement statewide fishing regulation change;

2015:

Develop population and habitat assessment program for Lake Champlain;
Continue Allegheny River watershed stocking and assessment program;
Conduct warmwater fish surveys in Lake Erie;

2016:

Conduct Lake Champlain percid surveys;
Conduct Lake Champlain creel survey;
Determine need and feasibility of a Lake Champlain stocking or transfer program;
Conduct Lake Champlain habitat suitability assessment and identify habitat restoration needs;
Continue Allegheny River watershed stocking and assessment program;
Conduct warmwater fish surveys in Lake Erie;

2017:

Continue Allegheny River watershed stocking and assessment program;
Initiate checks for spawning aggregations in the Allegheny River watershed;
Initiate habitat restoration projects in Lake Champlain;
Conduct warmwater fish surveys in Lake Erie;

2018:

Final year of stocking in Allegheny River watershed;
Continue young of year and spawning aggregation checks in the Allegheny River watershed;
Continue habitat restoration projects in Lake Champlain and monitor use;
Conduct warmwater fish surveys in Lake Erie;

2019:

Continue young of year and spawning aggregation checks in the Allegheny River watershed;
Continue habitat restoration projects in Lake Champlain and monitor use;
Conduct warmwater fish surveys in Lake Erie;

2020:

Conduct a sauger population survey of the Allegheny River watershed to determine success of stocking program and status of sauger in Conewango Creek;
Conduct creel survey of Allegheny River watershed;
Repeat Lake Champlain percid surveys;
Conduct warmwater fish surveys in Lake Erie;
Reassess statewide status of sauger and develop new management objectives and recommendations. This will include an assessment of the potential for sauger management in the Genesee, Black, and Seneca rivers.

Literature Cited

Ali, M. A. and M. Anctil. 1977. Retinal structure and function in the walleye (*Stizostedion vitreum vitreum*) and sauger (*S. canadense*). Journal of the Fisheries Research Board of Canada 34:1467-1474.

Anderson, J.K. 1978. Lake Champlain fish population inventory, 1971 to 1977. VT Department of Fish and Wildlife. Essex Junction VT.

Applegate, V.C. and H. D. Van Meter. 1970. A brief history of commercial fishing in Lake Erie. U.S. Fish and Wildlife Service Leaflet 630. 28 pp.

Becker, G. C. 1983. Fishes of Wisconsin. The University of Wisconsin Press, Madison, WI.

Bellgraph, B. J. 2006. Competition between sauger and walleye in non-native sympatry: historical trends and resource overlap in the Middle Missouri River, Montana. M.S. Thesis, Montana State University, Bozeman. 72 pp.

Billington, N., R. N. Koigi, B. D. S. Graeb, and D. W. Willis. 2004. Hybridization between sauger and walleye in Lewis and Clark Lake, South Dakota, determined by protein electrophoresis. Pages 115-116 in: T. P. Barry and J. A. Malison, editors. Proceedings of Percis III:The Third International Percid Fish Symposium, University of Wisconsin Sea Grant Institute, Madison.

Binding, C. E., J. H. Jerome, R. P. Bukata, W. G. Booty. 2007. Trends in water clarity of the lower Great Lakes from remotely sensed aquatic color. Journal of Great Lakes Research. 33:824-841.

Boshung, H.T., and R.L. Mayden. 2004. Fishes of Alabama. Smithsonian Books, Washington, D.C. 736 pp.

Carlander, K.D., and R. E. Cleary. 1949. The daily activity patterns of some freshwater fishes. American Midland Naturalist. 41:447-452.

Carlson, D. 2006. Species Account: Sauger (*Sander canadensis*). NYSDEC. Watertown, NY.

Carlson, D.M., R.A. Daniels and S.W. Eaton. 1999. Status of fishes of the Allegheny River watershed of New York State. Northeastern Naturalist 6(4):305-326.

Clay, W.M. 1975. The fishes of Kentucky. Kentucky Department of Fish and Wildlife Resources. Frankfort. 416 pp.

Crance. J. H. 1987. Preliminary habitat suitability index curves for sauger. Proceedings of the Southeast Association of Fish and Wildlife Agencies. Pp. 159-167.

Collette, B. B. and 7 co-authors. 1977. Biology of the percids. Journal of the Fisheries Research Board of Canada. 34:1890-1899.

Doan. K.H. 1941. Relation of sauger catch to turbidity in Lake Erie. Ohio Journal of Science. 41: 449-452.

Eaton, S.W., R.J. Nemecek and M.M. Kozubowski. 1982. Fishes of the Allegheny River above Kinzua Dam. N.Y. Fish and Game J. 29(2):189-198.

Elser, A.A., R.C. MacFarland, and D. Schwehr. 1977. The effects of altered streamflows on the fish of the Yellowstone and Tongue Rivers, Montana. Technical Report No. 8. Yellowstone Impact Study. Montana Department of Natural Resources and Conservation, Helena, Montana.

Environment Canada and USEPA. 2006. State of the Great lakes 2005. EPA 905-R-06-001. 305 pp.

Etnier, D.A. and W.C. Starnes. 1993. The fishes of Tennessee. University of Tennessee. University of Tennessee Press, Knoxville. 681pp.

Fisheries Technical Committee. 2009. Strategic Plan for Lake Champlain Fisheries. Lake Champlain Fish and Wildlife Management Cooperative, USFWS, Essex Junction, VT

Forney, J. L., L. G. Rudstam, D. M. Green, and D. L. Stang. 1994. Percid Sampling Manual. Chapter 3 in Fish Sampling Manual: Guidelines for the collection, analyses and interpretation of fisheries data by units of the New York State Department of Environmental Conservation, Bureau of Fisheries. NYSDEC, Albany, NY.

Fowler, H. W. 1919. A list of fishes of Pennsylvania. Proceedings of the Biological Society of Washington 32:49-74.

Gardner, W.M. and R.K. Berg. 1980. An analysis of the instream flow requirements for selected fishes in the Wild and Scenic portion of the Missouri River. Montana Fish, Wildlife and Parks report, Great Falls, MT.

Gardner, W.M. and P.A. Stewart. 1987. The fishery of the lower Missouri River, Montana. Montana Department of Fish, Wildlife and Parks report, FW-2-R.

Gebkin, D.F. and K.J. Wright. 1972. Walleye and sauger spawning areas study, Pool 7, Mississippi River 1960-1970. Wisconsin Department of Natural Resources Management Report No. 60. 25pp.

Goodyear, C.S., T.A. Edsall, D.M. Ormsby Dempsey, G.D. Moss, and P.E. Polanski. 1982. Atlas of the spawning and nursery areas of Great Lakes fishes. Volume eleven: Lake Ontario. U.S. Fish and Wildlife Service, Washington, D FWS/OBS-82/52.

Graeb, B.D.S. 2006. Sauger population ecology in three Missouri River mainstem reservoirs. Doctoral Dissertation, South Dakota State University, Brookings, SD. 83pp.

Greeley, J. 1928. Fishes of the Oswego watershed. pp. 84-107. In A biological survey of the Oswego River system. Suppl. Seventeenth Ann. Rept. (1927). New York Conserv. Dept. Albany.

Groen, C.L. and J.C. Schmulbach. 1978. The sport fishery of the unchannelized and channelized middle Missouri River. Transactions of the American Fisheries Society 107:412-418.

Halnon, L. C. 1963. Historical survey of Lake Champlain's fishery. Vermont Fish and Game. Job Completion Report F-1-R-10 Job 6. Essex Junction, VT. 96pp.

Hesse, L. W. 1994. The status of Nebraska fishes in the Missouri River. 6. Sauger (Percidae: *Stizostedion canadense*). Transactions of the Nebraska Academy of Sciences 21:109-121.

Holland, L.E. 1985. Survey of Ichthyoplankton drift at Lock and Dam 5 Upper Mississippi River. U.S. Fish and Wildlife Service, National Fishery Research Center, La Crosse, Wisconsin. 25 pp.

Ickes, B.S., A.G. Stevens, and D. L. Pereira. 1999. Seasonal districbution, habitat use, and spawning locations of walleye *Stizostedion vitreum* and sauger *S. canadense* in Pool 4 of the Upper Mississippi River, with special emphasis on winter distribution related to a thermally altered environment. Minnesota Department of Natural Resources, Investigational Report 481, St. Paul. 30 pp.

Jaeger, M.E., A.V. Zale, T.E. McMahon, and B.J. Schmitz. 2005. Seasonal movements, habitats use, aggregation, explotation, and entrainment of saugers in the lower Yellowstone River: an empirical assessment of factors affecting population recovery. North American Journal of Fisheries Management 25:1550-1568.

Kitchell, J.F., M.G. Johnson, C.K. Minns, K.H. Loftus, L. Grieg, C.H. Oliver. 1977. Percid habitat: the river analogy. Journal of the Fisheries Research Board of Canada 34:1936-1940.

Koonce, J.F., T.B. Bagenal, R.F. Carline, K.E.F. Hokanson, and M. Nagiec. 1977. Factors influencing year-class strength of percids: a summary and model of

temperature effects. Journal of the Fisheries Research Board of Canada 34:1900-1909.

Koryak, M., P. Bonislawsky, D.D. Locy and B.A. Porter 2009. Typical channel fish assemblage of the recovering lower Allegheny River navigation system, Pennsylvania USA. J Freshw. Ecol. 24(3):509-517.

Krueger, K.L., W.A. Hubert, and M.M. White. 1997. An assessment of population structure and genetic purity of sauger in two high-elevation reservoirs in Wyoming. Journal of Freshwater Ecology 12:499-509.

Leonardi, J.M. and M.V. Thomas. 2000. An assessment of the Huron River walleye population. State of Michigan Department of Natural Resources, Fisheries Division Technical Report. 97-2. Lansing, MI.

Lorantas, R., D. Kristine, and C. Hobbs. 2005. Sauger management and fishing in Pennsylvania. Pennsylvania Fish and Boat Commission Warmwater Unit. http://www.fish.state.pa.us/pafish/sauger/00sauger_overview.htm.

Mammoliti, C.S. 2007. Misssissippi Interstate Cooperative Resource Association: Sauger Management investigation. Report to the MICRA Gamefish Committee. June 2007. Watershed Institute, Inc., Topeka, Kansas. 98 pp.

McMahon, T.E. 1999. Status of sauger in Montana. Montana Fish, Wildlife and Parks report. Helena, MT.

McMahon, T.E. and W.M. Gardner. 2001. Status of sauger in Montana. Intermountain Journal of Sciences. 7:1-21.

Meek, S.E. 1889. Notes on fishes of Cayuga Lake basin. Ann. New York Acad. Sci., 4:297-316.

Mero, S.W. 1992. Food habits of walleye and sauger in Lake Sakakawea, North Dakota. Master's Thesis. South Dakota State University, Brookings, SD. 103 pp.

Nelson, W.R. 1968. Reproduction and early life history of sauger, *Stizostedion canadense*, in Lewis and Clark Lake. Transactions of the American Fisheries Society 97:159-166.

Nelson, W.R. 1969. Biological characteristics of the sauger populations in Lewis and Clark Lake. Technical Papers No. 21. U.S. Bureau of Sport Fisheries and Wildlife, Washington, D.C. 11 pp.

Nelson, W.R. and C.H. Walburg. 1977. Population dynamics of yellow perch (Perca flavescens), sauger (Stizostedion canadense), and walleye (S. vitreum vitreum) in

four main stem Missouri River reservoirs. Journal of the Fisheries Research Board of Canada 34:1748-1763.

Nettles, D.C., C.D. Martin, N.R. Staats. 2005. South Bay, Lake Champlain walleye and sauger assessments, 2003-2004. Draft Report. USFWS, RayBrook (DEC office), NY 22 pp.

NYSDEC. 2006a. Comprehensive Wildlife Conservation Strategy. New York State Department of Environmental Conservation. Albany, NY.

NYSDEC. 2006b. Fish passage at Springville Dam: a review of fisheries issues. Region 9 and Lake Erie Fisheries Unit technical report.

Osterberg, D.M. 1978. Food consumption, feeding habits, and growth of walleye (Stizostedion vitreum) and sauger (Stizostedion canadense) in the Ottawa River near Ottawa-Hull, Canada. Ph.D. Univerisity of Ottawa. 136 pp.

Page, L.M. and B.M. Burr. 1991. A field guide to freshwater fishes: North America north of Mexico. Houghton Mifflin Company, Boston, Massachusetts. 432 pp.

Pegg, M.A., J.B. Layzer, and P.W. Bettoli. 1996. Angler exploitation of anchor-tagged saugers in the lower Tennessee River. North American Journal of Fisheries Management 16:218-222.

Pegg, M.A., P.W. Bettoli, and J.B. Layzer. 1997. Movement of saugers in the lower Tennessee River determined by radiotelemetry, and implications for management. North American Journal of Fisheries Management 17:763-768.

Penkal, R.F. 1992. Assessment and requirements of sauger and walleye populations in the lower Yellowstone River and its tributaries. Montana Department of Fish, Wildlife and Parks. Report F-22-13. 149 pp.

Pitlo, J., Jr. 1985. Completion report wing dam and closing dam investigations: walleye and sauger use of wing and closing dam habitat as determined by radio telemetry. Iowa Conservation Commission, Des Moines. 56 pp.

Pitlo, J., Jr. 1992. Walleye and sauger (Stizostedion spp.) in the Upper Mississippi River: early life history. Upper Mississippi River Conservation Committee, Rock Island, Illinois. 39 pp.

Pitlo, J., Jr. B. Brecka, M. Stopyro, K. Brummett, and G. Jones. 2004. Sauger (*Stizostedion canadense*). Pages 187-197 In: J. Pitlo and J. Rasmussen, editors, UMRCC Fisheries Compendium, 3rd edition.

Preigel, G. R. 1963. Food of walleye and sauger in Lake Winnebago, Wisconsin. Transactions of the American Fisheries Society 92:312-313.

Preigel, G. R. 1969. The Lake Winnebago sauger-age growth, reproduction, food habits, and early life history. Wisconsin Department of Natural Resources Technical Bulletin No. 43. 63 pp.

Preigel, G. R. 1983. Sauger life history, ecology, and management. Wisconsin Department of Natural Resources, Madison.

Rawson, M.R. and R.L. Scholl. 1978. Reestablishment of sauger in western Lake Erie. Pages 261-265 in R.L. Kendall, editor, Selected coolwater fishes of North America. American Fisheries Society Special Publication 11. Bethesda, MD.

Regier, H.A., V.C. Applegate, and R.A. Ryder. 1969. The ecology and management of the walleye in western Lake Erie. Great Lakes Fisheries Commission Technical Report 15, Ann Arbor, Michigan.

Reyjol, Y., P. Brodeur, Y. Mailhot, M. Mingelbier, and P. Dumont. 2010. Do native predators feed on non-native prey? The case of round goby in a fluvial piscivorous fish assemblage. Journal of Great Lakes Research 36: 618–624.

Rohde, F.C., R.G. Arndt, D.G. Lindquist, and J.F. Parnell. 1994. Freshwater fishes of the Carolinas, Virgina, Maryland, and Delaware. University of North Carolina Press, Chapel Hill. 222 pp.

Roseman, E.F, W.W. Taylor, D. B. Hayes, J. Fofrich, and R. L. Knight. 2002. Evidence of walleye spawning in Maumee Bay, Lake Erie. Ohio Journal of Science 120:51-55.

Ross, S.T. 2001. The inland fishes of Mississippi. University Press of Mississippi, Jackson. 624 pp.

Ryan, P.A., R. Knight, R. MacGregor, G. Towns, R. Hoopes, and W. Culligan. 2003. Fish-community goals and objectives for Lake Erie. Great Lakes Fish. Comm. Spec. Publ. 03-02. 56 p.

Scott, W.B. and E.J. Crossman. 1998. Freshwater Fishes of Canada. Fisheries Research Board of Canada, Ottawa. 966 pp.

Schell, S. A., R.S. Hale, S.M. Xenakis, C.J. O'Bara, D.T. Henley, T.C. Stefanavage, and L.D. Franklin. 2004. Ohio River Percid Investigation: Ohio River Fisheries Management Team, Technical Committee Final Report No. 2004.1, Ohio Department of Natural Resources

Seigwarth, G.L., J. Pitlo, D.W. Willis, and A.L. Thompson. 1993. Walleye and sauger spawning habitat survey in Pool 16 of the Upper Mississippi River. Project

Completion report. South Dakota State University – South Dakota Cooperative Fish and Wildlife Research Unit, Brookings, SD. 44 pp.

Smith, C. L. 1985. The inland fishes of New York State. New York State Department of Environmental Conservation. Albany, NY. 522 pp.

Smith, P. W. 2002. Fishes of Illinois. University of Illinois Press, Urbana. 352 pp.

Stroud, R.H. 1948. Notes on the growth of hybrids between the sauger and the walleye (*Stizostedion canadense canadense* x *S. vitreum vitreum*) in Norris Reservoir, Tennessee. Copeia 1948:297-298.

Swenson, W.A. and L.L. Smith. 1976. Influence of food competition, predation, and cannibalism on walleye (Stizostedion vitreum vitreum) and sauger (S. canadense) populations in Lake of the Woods, Minnesota. Journal of the Fisheries research Board of Canada 33:1946-1954.

Thiem, J. D., T. R. Binder, P. Dumont, D. Hatin, C. Hatry, C. Katopodis, K. M. Stamplecoskie, and S. J. Cooke. 2012. Multispecies fish passage behavior in a vertical slot fishway on the Richelieu River, Quebec, Canada. River Research and Applications.

Walburg, C.H. 1972. Some factors associated with fluctuation in year-class strength of sauger, Lewis and Clark Lake, South Dakota. Transactions of the American Fisheries Society 101:311-316.

Ward, N.E., III. 1992. Electrophoretic and morphological evaluation of Stizostedion species collected from Lake Sakakawea, North Dakota. Master's Thesis. South Dakota State University, Brookings, SD.

Welker, M.T., E.L. Roberts, L.K. Stahl, and J. Wendel. 2002. Seasonal habitat use and habitat preference for sauger in the Big Horn River, Wyoming. Administrative Report CY-2LB-511-02. Wyoming Game and Fish Department, Cheyenne, WY. 19 pp.

Werner, R. G. 2004. Freshwater Fishes of the Northeastern United States. Syracuse University Press. Syracuse, NY. 335 pp.

Wisconsin DNR. 2005. Winnebago Walleye News. Fish and Habitat Survey Report for Winnebago County. Madison, WI. 8 pp. http://dnr.wi.gov/fish/reports/final/winnebagowalleye2005.pdf