Review of Grasse River Lake Sturgeon Habitat Use and Possible Post-Superfund Remediation Agency Actions

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Cooperator Report

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Executive Summary

The Grass River (hereafter Grasse River) historically served as a major source of fisheries production for the Saint Lawrence River (hereafter St. Lawrence River) basin, providing critical spawning habitat and support for other life history stages of numerous species including the culturally and ecologically significant Lake Sturgeon (*Acipenser fulvescens*). Decades of environmental degradation resulted in designation of the lower Grasse River as the Grasse River Superfund site and part of the St. Lawrence River Area of Concern (AOC) at Massena/Akwesasne. The primary problems were severe contamination of sediments and fish, with numerous environmental beneficial use impairments (BUIs) including losses and degradation of habitat and diminished animal populations that limited fisheries production and reduced ecosystem services provided by the Grasse River. Efforts to restore the lower Grasse River within the AOC were initiated in 2019 to remove or isolate contaminants, repair damaged habitats, and rebuild fish and wildlife populations. The purpose of this report is to 1) summarize the history and contemporary status of environmental conditions and fisheries in the Grasse River, with an emphasis on Lake Sturgeon; 2) summarize remediation and restoration activities

and how they may affect fisheries habitat and populations; and 3) discuss potential options for continued habitat remediation in addition to currently proposed restoration actions.

Grasse River Lake Sturgeon Habitat and Fisheries

The 185-km Grasse River extends from the Adirondack Mountains to the St. Lawrence River and contains a variety of riverine habitats that support diverse cold and cool-water fish assemblages, of most notable concern is the Lake Sturgeon due to its cultural and ecological values. The lower 51 km of the river is free-flowing, with the first dam at Madrid, NY. Lake Sturgeon is a long-lived fish found in rivers and lakes across eastern North America. Due to exploitation, it is thought that Lake Sturgeon populations are less than 1% of their former size. In 1983, New York State listed the Lake Sturgeon as a state-threatened species and, in 2005, the Canadian St. Lawrence/Great Lakes population was listed as ‘Special Concern,’ but relisted as ‘Threatened’ the following year. A 1995 New York recovery plan aimed to maintain populations in the St. Lawrence and Grasse rivers and to restore populations in the Saint Regis River (hereafter St. Regis River). A stocking program in the St. Lawrence, St. Regis, and Raquette rivers resulted in Lake Sturgeon now found in all water bodies targeted for recovery.

Lake Sturgeon adults are highly migratory and the fish residing in the St. Lawrence River and its tributaries are likely one population. Lake Sturgeon have been found in all St. Lawrence River AOC tributaries, but several dams and other obstacles currently or historically have prevented access to upstream areas including the weir at Massena, NY, and the Madrid Dam on the Grasse River. However, the weir at Massena was breached in 1997, allowing fish to migrate upstream to the Madrid Dam.

A number of Lake Sturgeon studies have been performed in the Grasse River, including population and movement surveys, habitat mapping/delineation, and studies focused on reproduction. The majority of Lake Sturgeon mortality occurs during the early life stages, typically before achieving a total length of ~25 cm, or when fish are large enough to avoid predation. The choice of high quality spawning habitat by adult fish influences egg survival. Suitable Lake Sturgeon spawning habitat typically has large substrate sizes, high flows (0.6–1 m/s), and shallow depths (0.75–5.5 m) within larger rivers and adults show strong spawning site fidelity. In the Grasse River, adults begin to stage outside the spawning area when temperatures reach 7–10 °C and broadcast spawning is initiated at 10–12 °C. Eggs typically hatch within 5–14 days depending on temperature; egg mortality is as high as 99% due to predation, adverse environmental conditions, fungus, or sedimentation. In the Grasse River, spawning adults or eggs have been observed at the Madrid Dam and at the breached weir of Massena Rapids. Based on geomorphology and water velocities, there are six potential Lake Sturgeon spawning locations downstream of the Madrid Dam.

Once hatched, Lake Sturgeon larvae typically stay in the substrate until they can feed exogenously and leave the substrate to drift with the current at night. Due to the potentially large spatial scale and duration of drift, predation rates on drifting larvae are unknown and hydrological variables are thought to influence survival during drift. Little is known about where or why larvae fall out of drift and it is unclear whether they exhibit habitat preference, or if they drift until velocities decrease to allow for settling. In the Grasse River, no Lake Sturgeon larvae have been found during any of the studies.

Once drift has ended, age-0/young-of-year (YOY) fish are typically found in low-flow shallow waters, but have also been found in deeper, offshore habitats where they appear to prefer fine substrates devoid of vegetation with abundant invertebrate prey. In the Grasse River, YOY Lake Sturgeon have been found to occupy shallow (<2 m), low-flow habitats. Adult and juvenile (<100 cm total length) Lake Sturgeon are present year-round in the Grasse River. Based on tagging studies, Lake Sturgeon used middle and lower river habitats and were most active during March through late May. Fish also moved into the St. Lawrence River.

Superfund and AOC Restoration Management Actions

Physical habitat alterations in the lower river (from Massena, NY, downstream) began in the late 1800s when efforts to channelize and divert water from the river for industrial activities commenced. In the mid-20th century, extensive discharges and land-based dumping of chemical waste, mostly polychlorinated biphenyls (PCBs), led to designation of the lower 11.6 km of the Grasse River from the Massena Power Canal to the mouth of the St. Lawrence River as a Superfund site.

Appendices to this technical report contain summaries of the reports prepared by Arconic (formerly Alcoa Inc.) detailing their Superfund remediation plans with considerations for Lake Sturgeon and reports on the pre-existing habitat conditions in the Grasse River. While no spawning locations are located within the remediation area, Arconic has specified that no in-water work will occur upstream of transect T6 during April 1 - June 15 and bank-to-bank work will not occur downstream of T6 to allow the passage of Lake Sturgeon to potential staging/spawning sites upstream. Additionally, Arconic has specified that the cap material (8 - 25 cm cobbles) to be placed at T1–T6 will be “suitable for Lake Sturgeon spawning and larval drift habitat” as well as potential spawning habitat for other lithophilic-spawning fish species.

There is the possibility that after June 15, bank-to-bank remediation work will occur at some point, blocking the way between the lower and middle river. This may not be detrimental to Lake Sturgeon, as eighty percent of Lake Sturgeon tagged in the middle river stayed there throughout the duration of that study, while some migrated to the St. Lawrence River. Precautions will be taken to minimize the risk of injuring or killing Lake Sturgeon from physical dangers (e.g., collision with equipment and boat propellers, sediment burial) during remediation activities. These precautions include adjusting the timing of remediation activities, installing borders to isolate fish from activity zones, and maintaining a vigilant lookout for fish.

A habitat layer will be placed over two-thirds of the armored cap between T6 and T21 to support re-establishing a benthic macroinvertebrate forage base, the primary food source for Lake Sturgeon. Lake Sturgeon diet includes benthic invertebrates that use soft substrates (e.g., Chironomidae) and harder substrates (e.g., Ephemeroptera). Colonization of benthic invertebrates after disturbance is a relatively fast process, especially for Chironomidae. There has been evidence that benthic invertebrate populations may not recover effectively in sediment with activated carbon or, conversely, benthic invertebrates may have sub-optimal growth or nutritional status in areas without activated carbon. This potential limitation to an optimal food base in the remediated area is offset by the fact that Lake Sturgeon are a highly mobile species, with the ability to move to areas of more abundant food if necessary.

<u>Agency Actions for Lake Sturgeon</u>

Potential agency actions with the goal of improving Lake Sturgeon populations and habitat within the remediation area are included below. Note that the geographic scale of the potential agency actions include the St. Lawerence River AOC and its tributaries due to the migratory ecology of Lake Sturgeon. The New York State Department of Environmental

Conservation 2018 Lake Sturgeon Recovery Plan includes three primary management actions for the management unit that includes the Grasse River:

- Population monitoring in the St. Lawrence River and tributaries. Baseline stock assessment and population modeling for at least five years.
- Release of hatchery-reared fish planned for each year to 2023.
- Assessment and mapping of critical Lake Sturgeon habitat in the St. Lawrence River and tributaries, including further development of habitat suitability index models.

The main objectives and actions identified by multiple Lake Ontario and St. Lawrence River management agencies for achieving Lake Sturgeon protection and recovery are:

- Protect or increase extant Lake Sturgeon populations at an abundance commensurate with the capacity of their habitat to support them and the existing fish community.

- Maintain, enhance, and where feasible, restore habitat to support Lake Sturgeon.

- Restore Lake Sturgeon populations in locations where they have become extirpated, where feasible, and where functional habitat exists.

- Develop local scale Lake Sturgeon management strategies.

- Increase public awareness of the cultural and ecological significance and uniqueness of Lake Sturgeon and the importance of maintaining, enhancing, and restoring Lake Sturgeon populations.

- Address knowledge gaps to enable and enhance protection, conservation, and recovery efforts.

Supplemental Habitat Restoration Options and Assessments for the Grasse River

Based on documented experiences at other aquatic habitat restoration projects and general aquatic ecology knowledge, this report provides details about additional possible restoration and management actions to supplement the Superfund remedy:

- Evaluate the potential for sediment and invertebrate community enhancement techniques for habitats in areas affected by remediation. This could include examination of land use practices in the upper watershed and development of a sediment budget for the river.
- Develop flow management models to evaluate run of river and other discharge dynamics to optimize thermal and flow habitat for Lake Sturgeon life history stage-specific survival.
- In the lower Grasse River, increase diversity of instream structures, particularly nearshore areas, to add diversity to habitat function and improve potential for aquatic organisms, multiple fish species, and multiple fish life history stages.
- Renovation of Massena Weir and Rapids to improve public and ecological function. The Massena Rapids area represents a restoration opportunity to replace remnants of the weir with natural riverine structure and habitat that could serve to improve aesthetics and enhance ecological function for fish passage and spawning habitat.
- Overall, a long-term multi-disciplinary assessment and monitoring program could be implemented to follow population trajectories and physical habitat performance. Monitoring Lake Sturgeon movement patterns and reproduction would elucidate spawning habitat effectiveness and fish use. Annual spawning surveys would reveal habitat use and could be used to develop an index of egg abundance/survival, spawning intensity, and spawning ecology. Standardized adult Lake Sturgeon netting would

provide an index of population abundance and health. Additional characterization of site-specific flow patterns and substrates may be required before consideration of any spawning habitat augmentation. Intensive benthic community monitoring would provide an index of food availability for Lake Sturgeon and an ecological indicator of river ecosystem health.

Introduction

The Grass River (hereafter Grasse River), or Nikentsiá:ke "full of large fishes" (Jock et al., 2017), is 185-km long, extending from Massawepie Lake in the Adirondack Mountains to the mouth at the Saint Lawrence River (hereafter St. Lawrence River; Figure 1). The river's habitat and fish assemblages change moving upstream to downstream, with upstream areas characterized by meanders, bedrock bottoms, shallow riffles, and a cold-water fish assemblage (Carlson, 1999), and downstream areas (from the mouth to Massena, NY) characterized by depositional substrates, deeper depths (typically <6 m, but up to 9 m; Kleinschmidt, 2015a), wider stretches (120–180 m; U.S. Environmental Protection Agency [USEPA], 2013), and lentic fish assemblages (Carlson, 1999). The length of the river from the Madrid dam (river kilometer 51) to the mouth at the St. Lawrence River has been designated as 'Significant Coastal Fish and Wildlife Habitat' by the New York State Department of Environmental Conservation (NYSDEC) due to the presence of important Muskellunge (*Esox masquinongy*) and Lake Sturgeon (*Acipenser fulvescens*) habitat (New York Department of State [NYSDOS], 1994).

Starting in the 1800s the lower Grasse River underwent dramatic anthropogenic changes. From 1898 to 1903 the Massena Power Canal (~4.5 km long, ~70 m wide) was constructed to divert water from the St. Lawrence River to the Power Dam in the Grasse River that provided electricity to the Alcoa Massena-West Plant (an aluminum and fabrication plant; now Arconic, Inc.) in Massena, NY (Arconic Inc., 2017a). To account for the increased discharge created by the Massena Power Canal and dam, the lower Grasse River was dredged and deepened from 1914 to 1918, and the river was deepened again after the 1950s due to the effects of the nearby Moses-Saunders Power Dam and Snell Lock on the St. Lawrence River (Arconic Inc., 2017a). These changes resulted in a river more than four meters deeper and 30–91 m wider than its historical state (Arconic Inc., 2017b). However, by the 1950s, the Massena Power Canal was no longer used for energy production and its flows were reduced (Alcoa Inc., 2001).

Superfund Site History

From the 1950s to the 1970s, Alcoa discharged polychlorinated biphenyls (PCBs) through five wastewater outfalls at the Massena-West plant to the Grasse River, the Massena Power Canal, and the nearby unnamed tributary, contaminating approximately 1.3 million m^3 of sediment over 131 hectares of the river (USEPA, 2013). In 1985, the NYSDEC ordered Alcoa to perform a land-based cleanup effort which took place from 1991–2001, and in 1989 the USEPA issued an Administrative Order to Alcoa to assess the extent of PCB contamination and initiate a remedy, thus designating the lower 11.6 km of the Grasse River from the Massena Power Canal to the mouth of the St. Lawrence River as a Superfund site (Figure 2; USEPA, 2013). Concurrently, the International Joint Commission of United States and Canada (IJC) designated the St. Lawrence River Area of Concern (AOC) to include sections of the St. Lawrence, Grasse, Raquette, and Saint Regis (hereafter St. Regis) rivers that had been affected by contaminants from a variety of sources (IJC, 1988). New York State Department of Health issued a 1990 fish consumption advisory specifying that no fish from the Grasse River should be eaten. In 1995, Alcoa performed a 'Non-Time-Critical Removal Action' (NTCRA), removing sediments with the highest concentrations of PCBs from the river (~2,300 m^3; USEPA, 2013), and in 1998 Alcoa remediated sediments in the unnamed tributary (Arconic Inc., 2017a) after which discharges of PCBs from the tributary were "virtually eliminated" (Alcoa Inc., 2001). In the years following these actions, Alcoa performed several sediment capping and ecological studies to assess possible remediation techniques for the remainder of the contaminated sediments in the river.

As of 2000, the surface sediments in the Grasse River were estimated to contain 15 mg/kg of PCBs on average, and the subsurface sediments (>30 cm deep) contained the highest levels (Alcoa Inc., 2001), which in some cases reached up to 837 mg/kg dry weight (at >2 m deep; Xu et al., 2012). While PCB concentrations in fish have declined since the NTCRA from upper bounds of ~270 mg/kg (~27 ppm, Smallmouth Bass *Micropterus dolomieu*) in the early 1990s to less than 40 mg/kg (~4 ppm, in three fish species tested) since 2008 (https://thegrasseriver.com/monitoringHistoricalResults.html), the Superfund site can only be deleted from the National Priority List (https://www.epa.gov/superfund/superfund-national-priorities-list-npl) once fish PCB concentrations equal 0.01 mg/kg. In 2013 USEPA approved a remedy for cleanup at an estimated cost of $165 million USD with an annual operations and maintenance cost of $950,000 USD (USEPA's Record of Decision; USEPA, 2013). The AOC currently has seven beneficial use impairments (BUIs) targeted for recovery: 'Restrictions on Fish and Wildlife Consumption,' 'Degradation of Fish and Wildlife Populations,' 'Fish Tumors or Other Deformities,' 'Bird/Animal Deformities or Reproductive Problems,' 'Degradation of Benthos,' 'Loss of Fish and Wildlife Habitat,' and 'Transboundary Impacts' (Fidler, 2017; https://www.epa.gov/great-lakes-aocs/). The removal of many of these BUIs will depend on the successful remediation of the Grasse River.

Superfund Remedy

The selection of a remedy was outlined in USEPA's Record of Decision (USEPA, 2013), and the plans for remediation of sediments and habitat reconstruction are outlined in reports by Arconic (Arconic Inc., 2017a,b). Three primary remediation activities will take place along transects T1–T72 (Figure 2) over the course of five years: nearshore dredging, nearshore backfilling, and main channel capping. Approximately 10 hectares of nearshore area (~40% of the nearshore area within T1–T72; ~83,000 m^3) will be dredged and backfilled with the “same construction grade as the original channel.” To prevent shoreline instability, areas with shoreline slopes <5:1 will be backfilled with sand (2–4% organic content [OC]), slopes 3:1–5:1 will be backfilled with a sand/gravel mixture (2–4% OC), and slopes >3:1 will be backfilled with cobble/gravel <10 cm (Arconic Inc., 2017b). Based on pilot studies, effects on water quality (e.g., resuspension) are anticipated to be low (for dredging) to negligible (for backfilling; Arconic Inc., 2017b). Two different cap designs (based on guidance from USEPA and US Army Corps of Engineers) will be used in the main channel: an armored cap from T1–T21 (23 hectares) and an unarmored isolation cap from T21–T72 (91 hectares). The armored cap was deemed necessary to prevent ice scour damage (Arconic Inc., 2017b). Both cap types must be assessed for such damage every 5 years (USEPA, 2013). The armored cap will be ~64 cm thick and will consist of a 15-cm chemical isolation layer, a 15-cm gravel filter layer, and 33 cm of 8–25-cm-diameter gravel/cobbles on top. From T1–T6 the cobbles will be left bare to provide interstitial habitat (Arconic Inc., 2017a), and T6–T21 will be covered by a ~3–5-cm sand (1–2% OC) ‘habitat layer’ (Arconic Inc., 2017b). The unarmored isolation cap will be 30 cm thick, consisting of a 15-cm layer of sand/granulated activated carbon (1% OC) and a 15-cm layer of sand (1% OC) on top (Arconic Inc., 2017b).

The proposed habitat reconstruction consists primarily of replanting aquatic and riparian vegetation (sourced from established vegetation elsewhere in the river) within a year of backfilling and placing structural features such as boulders and minimal large woody debris (Arconic Inc., 2017a). Post-remediation monitoring is planned to include a study of vegetation reestablishment and status surveys of native bivalve mussels, benthic macroinvertebrates, and Lake Sturgeon. These are scheduled to begin the year after construction is finished (except for mussel surveys, which will begin five years later to allow reseeding) and will continue annually for five years using an adaptive management process. While benchmarks for vegetation recovery are outlined, no other benchmarks have been set for recovery of biota (Arconic Inc., 2017a). Many possible target dates for BUI removal are affected by the end date of remediation, putting some of the anticipated impairment recovery dates after 2024 (Fidler, 2017).

Lake Sturgeon in the St. Lawrence and Grasse Rivers

The Lake Sturgeon is a long-lived fish found in rivers and lakes across eastern North America (Auer, 2004). Due to exploitation and habitat loss, it is thought that Lake Sturgeon populations are 1% of their former size (Haxton et al., 2014, Hay-Chmielewski and Whelan, 1997). In the St. Lawrence River, Lake Sturgeon fisheries began in the U.S. and Canada in the 1870s (COSEWIC, 2006; NYSDEC, 2018). U.S. harvest continued through the 1940s–1950s until population abundance declined to <20% of the original population (Carlson, 1999; Chalupnicki et al., 2011) and the commercial/sport fishery was closed in 1976 (with exceptions for the St. Regis Mohawk Tribe at Akwesasne; Carlson, 1995). In 1983, New York State listed the Lake Sturgeon as a state-threatened species (NYSDEC, 2018). Lake Sturgeon harvest continued in Canada until limitations were placed during 1987–1991, and in 2005 the St. Lawrence/Great Lakes population was listed as ‘Special Concern,’ but relisted as ‘Threatened’ the following year (COSEWIC, 2006); though populations in most of New York are currently considered stable or increasing (NYSDEC, 2018). The 1995 New York recovery plan aimed to maintain populations in the St. Lawrence and Grasse rivers and to restore the population in the St. Regis River; stocking programs in the St. Lawrence, St. Regis, and Raquette rivers resulted in sturgeon currently found in all water bodies targeted for recovery (Chalupnicki et al., 2011; Dittman et al., 2015).

Lake Sturgeon are highly migratory (Pollock et al., 2014) and it is likely that the fish in the St. Lawrence River and its tributaries are all one population based on wide-scale movement patterns observed in the system (Normandeau Associates Inc. [NAI], 2008; Trested et al., 2011) and genetic analysis of the St. Lawrence/Great Lakes population as a whole (Welsh et al., 2008). Lake Sturgeon have been found in all St. Lawrence AOC tributaries either year-round or seasonally (Carlson, 1995; Trested et al., 2011), but several dams and other obstacles have prevented access to upstream areas, including the weir at Massena and Madrid Dam on the Grasse River, Raymondville Dam on the Raquette River, and the Hogansburg Dam on the St. Regis River (Figure 1). The Hogansburg Dam was removed in 2016, opening up hundreds of kilometers of the St. Regis River and its tributaries to migratory fish (McKenna et al., 2015), and the weir at Massena on the Grasse River was breached in 1997, allowing fish to migrate upstream as far as the Madrid Dam (Trested and Isely, 2011).

A number of Lake Sturgeon studies have been performed in the Grasse River, including population and movement surveys (Carlson, 1999; Jock et al., 2017; Kleinschmidt, 2017; NAI, 2008; Trested and Isely, 2011; Trested et al., 2011), habitat mapping/delineation (Jock et al., 2013; Kleinschmidt, 2015a), and studies focused on reproduction (Jock, 2017; Jock et al., 2017; Kleinschmidt, 2016a). Arconic prepared reports detailing their Superfund remediation plans with considerations for Lake Sturgeon (Arconic Inc., 2017a,b) and reports on the pre-existing habitat conditions in the Grasse River (Alcoa, 2016; Arconic Inc., 2016a,b). To assess the potential effects of Superfund remediation on Lake Sturgeon in this system, we review these studies in the context of each life stage of the Lake Sturgeon (Figure 3) in the Grasse River / St. Lawrence River AOC, describing what we currently know, what effects remediation may have, and what further information may be needed to assess the status of each life stage (post-remediation).

Lastly, we provide an overview of possible post-remediation agency actions to assess the status of the Lake Sturgeon in Grasse River and maintain their use of the river as feeding and potential spawning habitat.

Overview of Lake Sturgeon Life Stages in the Grasse River

Eggs, Sac-Fry Larval Stage, and Spawning Habitat

The majority of Lake Sturgeon mortality, like many fish, occurs in the early-life stages, which for Lake Sturgeon occurs in the period before achieving a total length of ~25 cm, or before they are large enough to avoid predation (Auer and Baker, 2002). Survival from egg to age-0 (summer or fall) is estimated at <0.5% (Caroffino et al., 2010). The choice of quality spawning habitat by adult fish influences egg survival. Suitable Lake Sturgeon spawning habitat tends to exhibit large substrate sizes, high flows (0.6–1 m/s), and shallow depths (0.75–5.5 m in larger rivers; Baril et al., 2017; Kerr et al., 2011; Threader et al., 1998), and Lake Sturgeon exhibit strong fidelity to spawning sites (Baril et al., 2017). High quality spawning habitat consists of cobble (6.4–25.6 cm; Baril et al., 2017) or larger substrates (>15 cm; Threader et al., 1998), with large interstitial spaces (Caroffino et al., 2010) that protect the eggs from predation but also allow adequate water flow (and thus oxygenation) of the eggs. Spawning usually occurs below barriers (D'Amours et al., 2001), and current breaks, such as boulders, appear to be important (Kerr et al., 2011). Adults begin to stage outside the spawning area when temperatures reach 7–10 °C (COSEWIC, 2006), and spawning was initiated at 10–16 °C in the Grasse River (Kleinschmidt, 2015b). Eggs and sperm are broadcast by spawning adults into the rocky substrate and typically hatch within 5–14 days depending on temperature (Golder Associates Ltd, 2011). Egg mortality is as high as 99% (Dumont et al., 2011; Kempinger, 1988; Nichols et al., 2003), which could be due to predation by a variety of fish species (Caroffino et al., 2010;

Kempinger, 1988; Nichols et al., 2003), adverse environmental conditions (e.g., temperatures >20 °C, dissolved oxygen levels <7.5 mg/L, or increased discharge; Kempinger, 1988; Kerr et al., 2011; Wang et al., 1985), fungus, or sedimentation (Kempinger, 1988; Nichols et al., 2003).

In the Grasse River, Lake Sturgeon spawning behavior and/or eggs have been observed near the Madrid Dam during 1992–1995, 1997, and 2008 (Carlson, 1999; Jock, 2017), and more recently at the breached weir of Massena Rapids (2009 and 2016–2017; Jock, 2017; Jock et al., 2017) which is the only known spawning location within the boundaries of the St. Lawrence River AOC (Jock et al., 2017). Based on geomorphology, there could be six potential spawning locations with appropriate substrate and flows for Lake Sturgeon reproduction, but only two riffles identified were within the AOC boundary and none were found within the boundaries of the planned remediation area (Jock et al., 2013). Similarly, Kleinschmidt (2015a) using GIS modeling, did not identify any spawning habitat in the lower Grasse River other than at Massena Rapids. An egg trap study at one of the potential spawning riffles upstream of the remediation area (Chamberlin Corners) found no Lake Sturgeon eggs in 2016 (April 14–May 24; Jock, 2017). Water quality in the Grasse River was found to be "generally acceptable" and velocities were high enough (0.1–2.0 m/s) for Lake Sturgeon spawning, but during low-discharge years early-summer month temperatures may be too high and dissolved oxygen too low for optimal survival of eggs and larvae (Bonner et al., 2015; Fuller et al., 2017).

While no spawning locations are located within the Superfund remediation area, Arconic has specified that no in-water work will occur upstream of T6 during April 1–June 15 and bank-to-bank work will not occur downstream of T6 to allow the passage of Lake Sturgeon to potential staging and spawning sites upstream (Arconic Inc., 2017b). These dates seem appropriate and are in line with those when spawning activities and eggs have been previously observed in the Grasse River (April 15–May 7; Carlson, 1999; Jock, 2017; Jock et al., 2017). Kleinschmidt (2017) found that most Lake Sturgeon monitored with radio telemetry were most active from late March to mid-May, moving throughout the study area. It is unclear in the remediation plan whether in-river work will occur prior to April 15 when Lake Sturgeon may be migrating to staging areas, although consideration of migratory species is integral to the remediation (USEPA, 2013).

As part of the remediation, Arconic has specified that the cap material (8–25 cm cobbles) to be placed at T1–T6 will be "suitable for Lake Sturgeon spawning and larval drift habitat" (Arconic Inc., 2017b) as well as potential spawning habitat for a number of other lithophilic fish species, but also state that "The substrate and velocities will provide suitable spawning habitat, but there is no certainty that the Lake Sturgeon will use the area for spawning or instead continue to move farther upstream to spawn" (Arconic Inc., 2017a). However, it appears that significant amounts of sedimentation may occur in these transects, based on sediment surveys performed by Arconic in September 2015, although data are only available for transects T2 and T5, plus T7-T9 which are just outside the area of interest for spawning habitat (Arconic Inc., 2016a). While the nearshore and main channel sites surveyed at T2 had substantial amounts of boulders, cobble, and gravel, 0–75% of these substrates were embedded with fines, and algae, leaf litter, and sticks/twigs were found throughout. At T5, the nearshore area was typically >45% fines with >50% embeddedness, and the main channel was 100% fines and also had algae, leaf litter, and sticks/twigs; T7 and T9 were similarly dominated by fines and debris (Arconic Inc., 2016a). Underwater video along these transects display a high density of suspended sediment and debris in the water, and fines were kicked up by the movement of the diver and by fish (Arconic Inc., 2016a). Overall, this appears to be a depositional area like much of the rest of the lower river, and lithophilic fish spawning substrates placed in this area may be lost to accumulation of fine sediments over time (Vaccaro et al., 2016).

Post-remediation construction monitoring of Lake Sturgeon movement patterns and reproduction are needed to understand the river's spawning habitat effectiveness. Given the multiple potential spawning sites and natural temporal variability in Lake Sturgeon reproductive efforts, a system-wide, long-term monitoring program across sites where spawning behaviors are known to occur (i.e., Madrid Dam and Massena Rapids) may be most effective to quantify egg deposition. A long-term monitoring strategy is especially important because Lake Sturgeon may not spawn due to environmental conditions (e.g., low discharge, adverse temperature regimes) or natural spawning periodicity (e.g., males 1–3 years, females >4 years; COSEWIC, 2006; Vélez-Espino and Koops, 2009). Long-term shore monitoring for spawning adults near potential spawning locations may be useful in determining if time and effort should be invested in additional egg capture studies in these riffles (e.g., Prichard et al., 2017; Roseman et al., 2011). Additional characterization of site-specific flow patterns and substrate may be required before executing spawning habitat augmentation (e.g., adding cobble to riffle areas) mentioned in several studies of the Grasse River (Baril, et al. 2019; Jock, 2013; Jock et al., 2017).

Meso-Larval Stage (Post Sac-Fry)

Once hatched, Lake Sturgeon larvae stay in the substrate until their yolk-sac is absorbed (usually 7–14 days post-hatch; Kempinger, 1988) and begin to drift at night (21:00–05:00; D'Amours et al., 2001) with the current when a temperature cue is met (e.g., 16 °C in the Black River, MI; Smith and King, 2005). At this point they can feed exogenously, but few larvae captured during drift have already fed (e.g., 1/845 in Kempinger, 1988). Depending on the length of the river, flow patterns, and the proximity to adequate habitat, larval Lake Sturgeon can drift

45 km downstream by 25–40 days post-spawn (Auer and Baker, 2002). In the Saint Clair River (hereafter St. Clair River), MI, drifting larvae were found most often along the bottom of the river, and as little as 4% were found higher in the water column during depth-stratified sampling (Young, 2015). However, in a shallower, "waist-deep" river, larvae were captured at similar rates throughout the water column (Kempinger, 1988), but this could be due to turbulent waters near the sampling site (Smith and King, 2005). Due to the potentially large spatial scale and duration of drift, predation rates on drifting larvae are unknown (Golder Associates Ltd, 2011). Little is known about where or why larvae fall out of drift and it is unclear if they exhibit habitat preference (Golder Associates Ltd, 2011; Krieger and Diana, 2016) or if they continue to drift downstream until velocities decrease to allow for settling (Auer and Baker, 2002). Anecdotal evidence suggests that larvae do not orient toward macrophytes for refuge (Threader et al., 1998).

In the Grasse River, no Lake Sturgeon larvae have been found in any of the egg capture studies previously performed (Carlson, 1999; Jock, 2017), nor in the 2015 study performed specifically to assess larval drift downstream of Massena Rapids over multiple weeks (Kleinschmidt, 2016a). Although Kleinschmidt (2016a) used depth-stratified conical nets randomly throughout the water column, depths were not reported. However, much of the total water column was likely sampled due to the size of the nets used (1-m diameter) and shallow water depths (3-4 m; Kleinschmidt, 2016a). The drift study could be improved in the future with more focus on D-frame nets, as most Lake Sturgeon larvae are found near the bottom based on the studies mentioned above.

The proposed dates (April 1–June 15) for no work at transects T1–T6 (Figure 2) is likely enough time for adult Lake Sturgeon to have passed through after spawning, but it is possible this time period could overlap with the larval drift period. Considering that spawning could occur in late May, and accounting for hatch time (5–14 days), yolk-sac absorption (start to drift 8–14 days post-hatch), and drift (some larvae drift 20 to 30 days post-hatch; Friday, 2014), larval drift could still occur long after spawning activities are observed. The timing and distance of Lake Sturgeon larval drift in the Grasse River is unknown. Krieger and Diana (2016) modeled larval habitat existing within 2 km of spawning habitat, but other larval studies have found larvae drifting farther downstream (D'Amours et al., 2001; Dumont et al., 2011; Friday, 2014).

Early Juvenile Stages (Age 0)

Once drift has ended, age-0/young of year (YOY) fish are typically found in shallow waters (<6 m), but have also been found in deeper, offshore habitats (Collier, 2018; COSEWIC, 2006; Kempinger, 1988; Kerr et al., 2011; Krieger and Diana, 2016). They appear to prefer fine substrates devoid of vegetation (COSEWIC, 2006; Kempinger, 1996; Threader et al., 1998) with an abundance of invertebrate prey (>3,000/m^2; Krieger and Diana, 2016), such as dipteran larvae and amphipods (Benson et al., 2005). They are found in lower-flow velocities than drifting larvae (< 1m/s; Auer and Baker, 2002; Benson et al., 2005; Krieger and Diana, 2016; Threader et al., 1998) and have been found in the shelter of large woody debris (Holtgren and Auer, 2004). Their home range is estimated to be quite small (<500 m of river length; Benson et al., 2005) and may only reside in riverine habitat during their first year of life before migrating to larger adjacent waterbodies (Caroffino et al., 2010). In the Grasse River, the age-0 fish may occupy shallow (< 2 m), low-flow habitats (Trested et al., 2011). Uncertainties exist about the critical habitat for YOY Lake Sturgeon (Pollock et al., 2014).

Age >1 Juveniles and Adults

Juveniles older than age 1 are most often associated with soft substrate, lower velocity flow, and depths of 0.5– 8 m in some systems and 6–20 m in systems where these depths are available (Boase et al., 2014; Haxton, 2011; Kerr et al., 2011). In the St. Regis River and the Genesee River, young juveniles were captured in the deepest available sites (6–8 m) and soft sediment was the most common substrate, but juveniles were also captured in river sections with mixed sand, gravel, and cobble (Dittman et al., 2007, 2015). Juvenile and adult Lake Sturgeon eat benthic macroinvertebrates and benthic fish (Kempinger, 1996; Nilo et al., 1997; Pollock et al., 2014). Primary Lake Sturgeon diet taxa are Chironomidae, Amphipoda and larger Crustacea, Ephemeroptera, and Mollusca (primarily Gastropoda and Sphaeriidae; Chiasson et al., 1997; Dittman et al. 2007; Kempinger, 1996). Adults and juveniles are present year-round in the Grasse River (Kleinschmidt, 2017; Trested et al., 2011).

In the Grasse River, no bank-to-bank remediation would occur downstream of transect T6 at any time to provide passage for Lake Sturgeon (Arconic Inc., 2017b). However, there is the possibility that after June 15 bank-to-bank remediation work at T1–T6 could occur at some point, blocking the way between the lower and middle river. This may not be entirely detrimental to juvenile and adult Lake Sturgeon, as previous movement studies found that most Lake Sturgeon tagged in a portion of the river stayed within that portion. Kleinschmidt (2017) found that eighty percent of Lake Sturgeon tagged in the middle river stayed there throughout the duration of the study, while others migrated through the lower river to the St. Lawrence River. Similarly, most fish tagged in the lower river were found foraging in the lower river, and only one fish tagged in the middle river was foraging in the lower river. This movement study also found that these Lake Sturgeon were most active from late March to mid-May, during which time there would be no bank-to-bank remediation.

The remediation of the Grasse River will include dredging of contaminated sediments and, while Arconic expects that resuspension into the water column will be low, it is possible that some PCBs could be resuspended. Following an experimental dredging pilot study, PCB loads in the water column and in tissues of other species of Grasse River fish increased temporarily (https://thegrasseriver.com/monitoringHistoricalResults.html). Lake Sturgeon are considered to exhibit "intermediate tolerance" to poor water quality (Barbour et al., 1999), but there is little information about the effects of chemical contaminants on Lake Sturgeon (Singer and Ballantyne, 2004), possibly due to species protections and small population sizes (Auer, 2004). As a large, long-lived benthic species, Lake Sturgeon are susceptible to bioaccumulation (Leonard et al., 2009; Moisan and Laflamme, 1999). PCBs have been detected at high levels (>2 ppm) that are unsafe for consumption in tissues of Lake Sturgeon from Wisconsin and Michigan (Hay-Chmielewski and Whelan, 1997; Larson, 1988), and some eggs of Lake Sturgeon captured near Montreal, Quebec, contained >2 ppm of coplanar PCBs (Ndayibagira et al., 1995). Retinoids are important for growth, reproduction, and the immune system, and Lake Sturgeon from PCB-contaminated sites had lower retinoid levels than those from non-contaminated sites near Montreal (Ndayibagira et al., 1995). Of 12 Columbia River fish species examined, White Sturgeon (*Acipenser transmontanus*) contained the highest body burdens of contaminants, and fish from a PCB-contaminated reservoir grew and matured slower and had low reproductive rates, but these effects were not conclusively linked to PCBs (Feist et al., 2005). Contaminants in benthic organisms consumed by other species of sturgeon have led to reduced reproduction, growth, and muscle generation (Feist et al., 2005; Webb et al., 2006). Monitoring PCB levels in fish and/or benthic organisms pre- and post-remediation may be useful in determining whether resuspension of PCBs is occurring in the system.

As part of the Grasse River remediation, a habitat layer will be placed over two-thirds of the armored cap between transects T6 and T21 to re-establish macroinvertebrates (Arconic Inc., 2017b). Benthic invertebrates are the primary food source for Lake Sturgeon, and much of the lower river targeted for remediation is used as foraging habitat by juvenile and adult fish (Kleinschmidt, 2015b; Trested et al. 2011). Macroinvertebrates can quickly colonize new sediment habitat, especially Chironomidae (Benke, 1998; MacKay, 1992), and community responses to sediment remediation or sediment placement can be variable, with changing community richness, diversity, or abundance for months to years post-remediation (Cornelissen et al., 2011; Kelaher et al., 2003; Kupryianchyk et al., 2012; Merritt et al., 2010). In some cases, no community changes attributed to carbon placement were observed (Janssen and Beckingham, 2013). The use of activated carbon has been shown to effectively reduce concentrations of PCBs in invertebrates in pilot studies in the Grasse River (Beckingham and Ghosh, 2011) and elsewhere (Patmont et al., 2015). Benthic invertebrate monitoring programs may aim to consider not only community changes but also toxicology of several taxa of interest. The pre-remediation community was typical of a depositional environment, and Diptera were the most common taxa present (Arconic Inc., 2016b). Using baseline invertebrate data collected in the study area (Arconic Inc., 2016b), community changes post-sediment remediation could be monitored to assess food availability for Lake Sturgeon. In limited cases, invertebrates in treated sediments may experience adverse toxicological or behavioral effects from activated carbon, although these effects may be reduced by using lower carbon concentrations and larger grained particles (Janssen and Beckingham, 2013; Jonker et al., 2009).

Possible Agency Actions: Grasse River Lake Sturgeon

Agency Actions for Lake Sturgeon

Potential agency actions with the goal of improving Lake Sturgeon populations and habitat within the remediation area are included below. Note that the geographic scale of the potential agency actions include the St. Lawerence River AOC and its tributaries due to the migratory ecology of Lake Sturgeon. New York State Department of Environmental Conservation 2018 Lake Sturgeon Recovery Plan includes three primary management actions for the management unit that includes the Grasse River.

- Population monitoring in the St. Lawrence River and tributaries. Baseline stock assessment and population modeling for at least five years.
- Release of hatchery-reared fish planned for each year to 2023.
- Assessment and mapping of critical Lake Sturgeon habitat in the St. Lawrence River and tributaries, including further development of habitat suitability index models.

The main objectives and actions identified by multiple Lake Ontario and St. Lawrence River management agencies for achieving Lake Sturgeon protection and recovery are:

- Protect or increase extant Lake Sturgeon populations at an abundance commensurate with the capacity of their habitat to support them and the existing fish community.
- Maintain, enhance, and where feasible, restore habitat to support Lake Sturgeon.
- Restore Lake Sturgeon populations in locations where they have become extirpated, where feasible, and where functional habitat exists.
- Develop local scale Lake Sturgeon management strategies.

- Increase public awareness of the cultural and ecological significance and uniqueness of Lake Sturgeon and the importance of maintaining, enhancing, and restoring Lake Sturgeon populations.

- Address knowledge gaps to enable and enhance protection, conservation, and recovery efforts.

Supplemental Habitat Restoration Options and Assessments for the Grasse River

Based on documented experiences at other aquatic habitat restoration projects and general aquatic ecology knowledge, this report provides details about additional possible restoration and management actions to supplement the Superfund remedy:

- Evaluate the potential for sediment and invertebrate community enhancement techniques for habitats in areas affected by remediation. This could include examination of land use practices in the upper watershed and development of a sediment budget for the river.
- Develop flow management models to evaluate run of river and other discharge dynamics to optimize thermal and flow habitat for Lake Sturgeon life history stage-specific survival.
- In the lower Grasse River, increase diversity of instream structures, particularly nearshore areas, to add diversity to habitat function and improve potential for aquatic organisms, multiple fish species, and multiple fish life history stages.
- Renovation of Massena Weir and Rapids to improve public and ecological function. The Massena Rapids area represents a restoration opportunity to replace remnants of the weir with natural riverine structure and habitat that could serve to improve aesthetics and enhance ecological function for fish passage and spawning habitat.

- Overall, a long-term multi-disciplinary assessment and monitoring program could be implemented to follow population trajectories and physical habitat performance. Monitoring Lake Sturgeon movement patterns and reproduction would elucidate spawning habitat effectiveness and fish use. Annual spawning surveys would reveal habitat use and could be used to develop an index of egg abundance/survival, spawning intensity, and spawning ecology. Standardized adult Lake Sturgeon netting would provide an index of population abundance and health. Additional characterization of site-specific flow patterns and substrates may be required before consideration of any spawning habitat augmentation. Intensive benthic community monitoring would provide an index of food availability for Lake Sturgeon and an ecological indicator of river ecosystem health.

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Figures

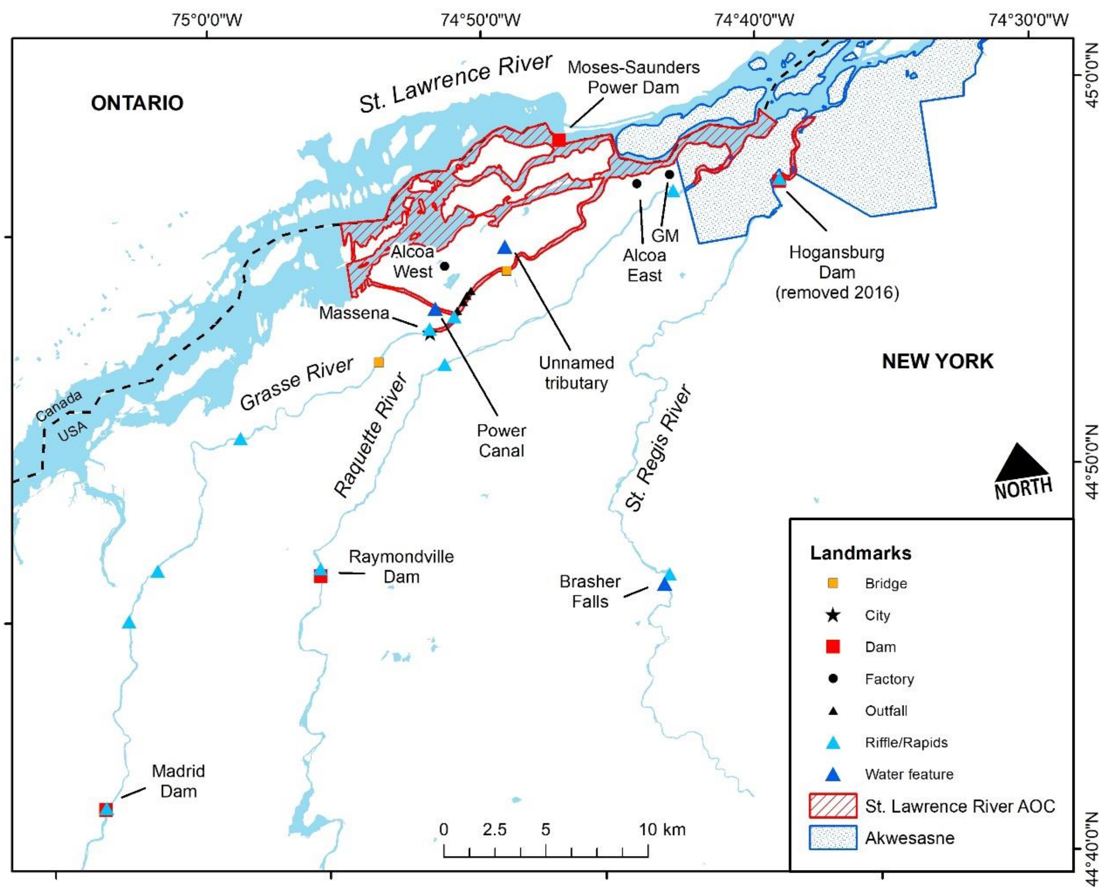

Figure 1. Overview of the Saint Lawrence River Area of Concern (AOC) and its connected tributaries (the Grass, Raquette, and Saint Regis rivers). Important landmarks and water features mentioned in this report. Riffles indicated are those identified in Jock et al. (2018). Maps were created using ArcGIS software by Esri. Base map data layers courtesy of: ESRI, U.S. Geological Survey, DMTI Spatial Inc, Tele Atlas, New York State Office of Cyber Security and Critical Infrastructure Coordination, and Canada Centre for Mapping and Earth Observation.

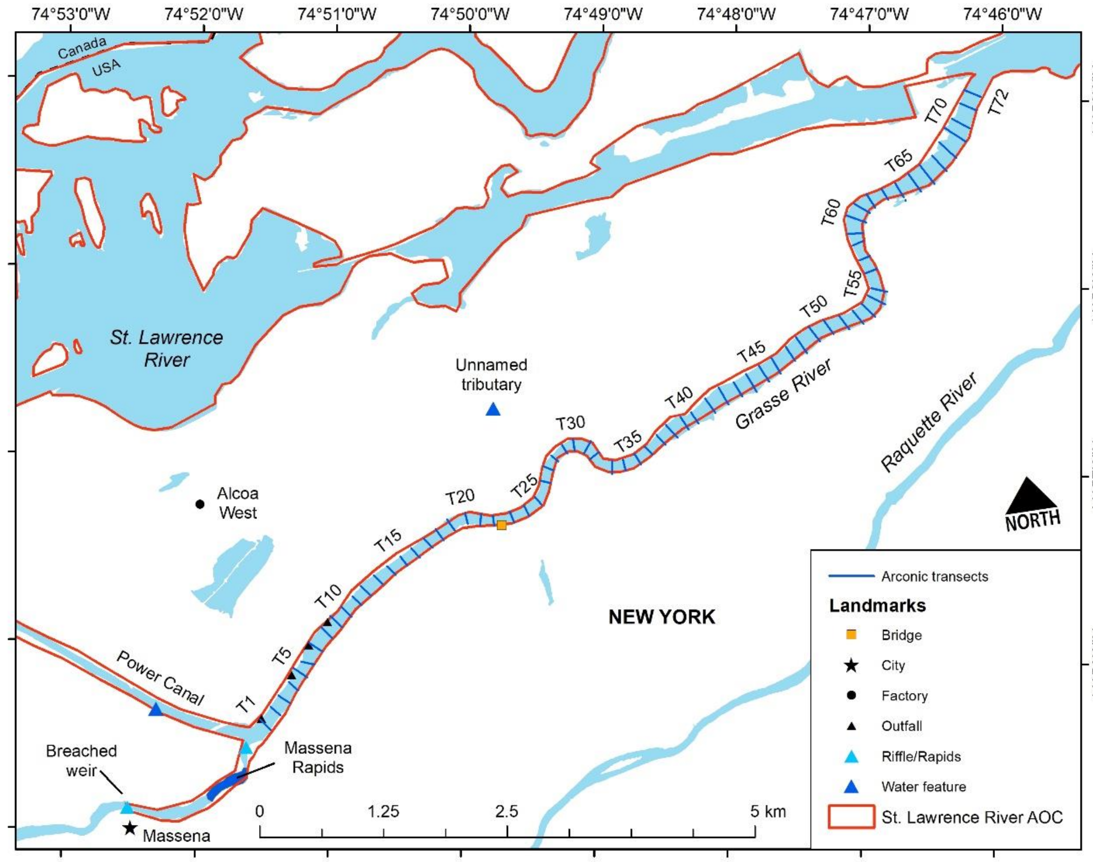

Figure 2. The section of the lower Grass River targeted for Superfund remediation (Arconic, formerly Alcoa, transects T1–T72) and associated landmarks and water features discussed in this report. AOC = Area of Concern. Maps were created using ArcGIS software by Esri. Base map data layers courtesy of: ESRI, U.S. Geological Survey, DMTI Spatial Inc, Tele Atlas, New York State Office of Cyber Security and Critical Infrastructure Coordination, and Canada Centre for Mapping and Earth Observation.

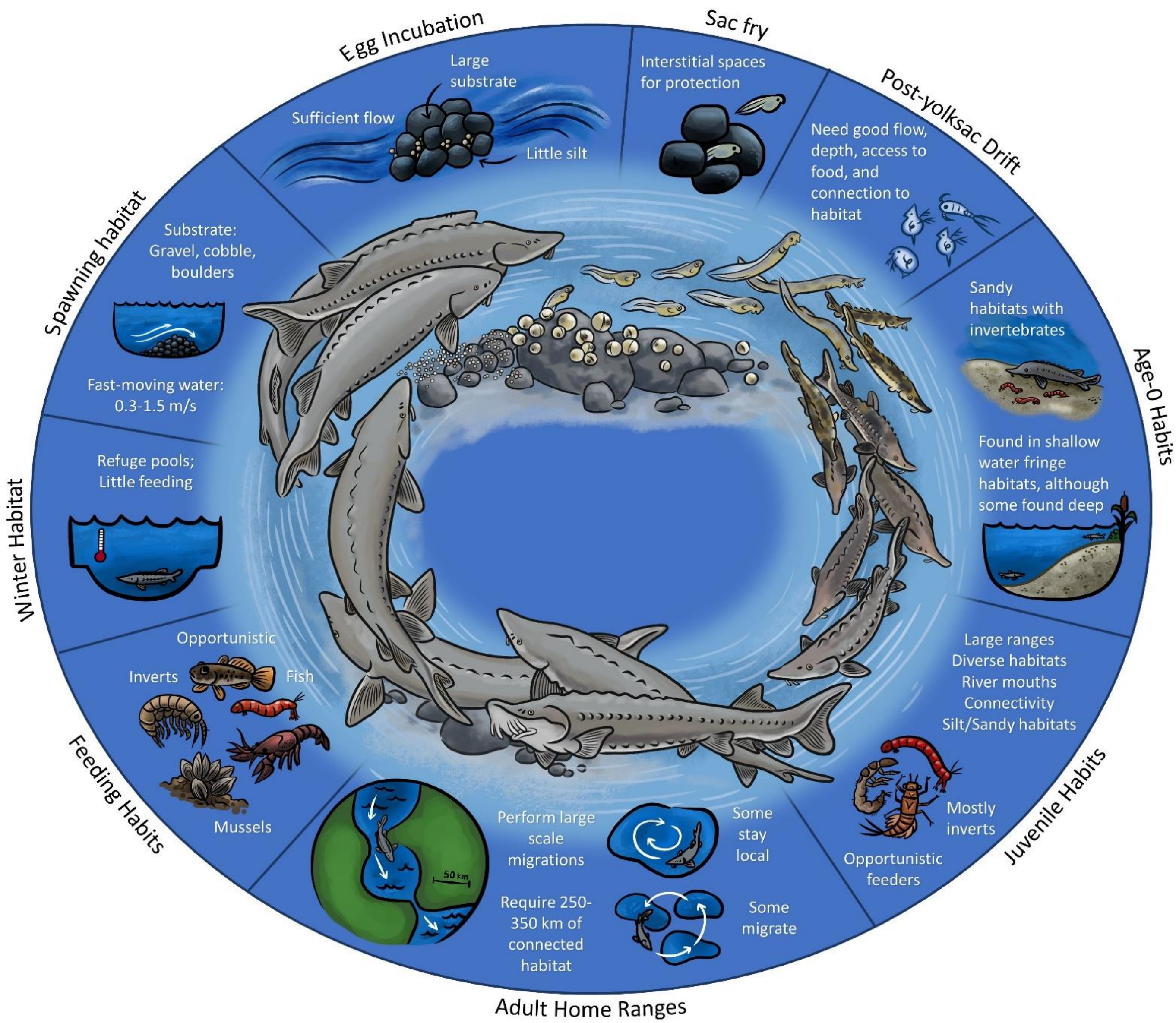

Figure 3. Lake Sturgeon (*Acipenser fulvescens*) life cycle and associated habitat use. Illustration credit: T.R. Tucker-Silva.

Appendix 1. Annotated Bibliography and Summary

This section includes summaries of selected studies and reports focused on the Grass River (hereafter Grasse River) remediation or Lake Sturgeon (*Acipenser fulvescens*). There are instances where abstracts or executive summaries (or portions thereof) have been presented with no additional interpretation deemed necessary. Additional information about the references and abbreviations used within directly quoted text should be addressed by reviewing the original source documents.

Arconic Inc., 2017b. Draft Biological Evaluation. Grasse River Study Area. Massena, New York. 135 pgs.

This report summarizes the life history characteristics and habitat summaries of several key taxa that could be affected by Superfund remediation in the Grasse River: Lake Sturgeon, Eastern Sand Darter (*Ammocrypta pellucida*), and Eastern Pond Mussel (*Sagittunio nasutus*). The Kleinschmidt reports (Kleinschmidt, 2015a, 2017, 2016b) are summarized for Lake Sturgeon. The remediation process is explained (e.g., relocation of outfall 001, staging area construction, shoreline clearing, removal of gas pipeline) and the construction equipment to be used are described: two material scows, one tugboat, one barge, and one support boat. The direct and indirect effects of construction are described for each species of concern. The nearshore dredging and backfilling are detailed: 24 acres will be dredged, no dredging will occur between April 1–June 15 for Lake Sturgeon spawning, dredging will move upstream to downstream, dredging will not be performed bank to bank so Lake Sturgeon may pass, and the only concern is possible loss of slope stability and short-term water quality issues associated with resuspension of dredged material. A majority of predicted juvenile and adult Lake Sturgeon habitat will be affected by the capping (85–90% of area is potential habitat), but very little will be affected by dredging (<1% of potential habitat area). Arconic anticipates that benthic invertebrates (benthos) will return shortly after an area is remediated (~1 year) and that by performing work in sections over multiple years the benthos should recolonize. The amount of area being remediated each year will comprise <25% of the overall available foraging area in any given year. Overwintering adult Lake Sturgeon should not be affected by dredging, and capping will reduce the water depth but not enough to affect the depth of the deep pools used. Spawning likely occurs upstream and out of the way of the remediation (i.e., in the Massena Rapids). It was suggested that larvae drifting down from the rapids could use the new coarse material from T1–T6 as habitat, or that the material used for the cap at T1–T6 could be used for spawning. It was also suggested that plantings/vegetation beds that will be added can add nursery and foraging habitat for young Lake Sturgeon. All workers on the river will be trained to identify Lake Sturgeon and any sightings will be reported. Bucket dredges are unlikely to hit Lake Sturgeon because the dredges are slow and vessel speeds will not exceed 5 mph so sturgeon will have time to move. There will be sufficient draft for Lake Sturgeon in the main channel under the vessels. Incidental take of Lake Sturgeon cannot exceed eight individuals and if it does EPA will be contacted to discuss next steps. No adverse effects of remediation were anticipated for Eastern Sand Darter or Eastern Pond Mussels.

From the introduction/purpose:

> "As discussed in the Habitat Delineation and Assessment Work Plan (Alcoa, September 2015a), New York State-listed endangered Lake Sturgeon (*Acipenser fulvescens*), are known to be present in the Grasse River. As part of the remedial design process, Arconic conducted a mesohabitat evaluation (Kleinschmidt, May 2015), a larval drift study (Kleinschmidt, February 2016a), and a radio-telemetry study (Kleinschmidt, August 2016b) to document Lake Sturgeon habitat and their use of the lower Grasse River. In addition, through consultation with the New York State Department of Environmental Conservation (NYSDEC) Natural Heritage Program (NYNHP) in May 2015, and as discussed in the Habitat Delineation and Assessment Report (Alcoa, March 2016a), the only other listed species with the potential to be present in the Grasse River remediation area was the eastern sand darter (*Ammocrypta pellucida*), a New York State listed threatened fish species. Five eastern sand darters were observed during the larval drift study in 2015. The eastern pond mussel (*Ligumia nasuta*) was observed during the 2016 mussel study; this species is not New York State- or federally listed, but at the request of the St. Regis Mohawk Tribe (SRMT) a specific assessment has been included in the biological evaluation due to its limited occurrences in northern New York.
> To protect fish and their habitat on other projects, the NYSDEC has imposed restrictions on when certain in water activities can be conducted. In general, these restrictions focus on limiting the timing, type, or extent of in-water work during all or part of the spawning and/or migratory season for the species of interest. On August 10, 2016, Alcoa submitted a technical memorandum describing proposed in-water restrictions specific to the Grasse River remedial construction. These restrictions primarily focused on protecting Lake Sturgeon spawning, larval drift, and passage. In part, because the results of the radio telemetry study (further discussed below) documented year-round use of the Grasse River by juvenile and adult Lake Sturgeon, NYSDEC requested (via email dated October 7, 2016) that a more extensive biological evaluation be completed in accordance with state regulation 6NYCRR Part 182. In subsequent discussions with NYSDEC on November 1, 2016, they indicated that all species listed in that regulation should be included in the biological evaluation, including the eastern sand darter. This biological evaluation was prepared based on the outline reviewed with the U.S. Environmental Protection Agency (USEPA), NYSDEC, and SRMT on November 1, 2016. […] Section 2 summarizes information from those studies that will be used to complete the biological evaluation and describes the existing habitat conditions in the project area. Section 3 summarizes the life history requirements of the Lake Sturgeon and the results of the 2015 and 2016 studies in the project area. Section 4 summarizes the life history requirements of the eastern sand darter and suitable habitat areas in the lower Grasse River, along with site-specific observations. Section 5 provides the key characteristics, life
> history requirements, habitat preferences, and range for the eastern pond mussel, and also presents site-specific observations from the 2016 mussel study. Section 6 summarizes the types of remediation activities that will be conducted in the lower Grasse River and the types of equipment that will be used. Section 7 describes the habitat reconstruction approach for areas disturbed by remediation activities. Section 8 discusses the potential direct and indirect effects to the listed species as a result of implementing the remediation

> projects. Section 9 discusses the conservation and mitigation measures that will be implemented to offset any of the potential effects."

Arconic Inc., 2017a. Draft Habitat Reconstruction Plan. Grasse River Study Area. Massena, New York. Massena, New York. 101 pgs.
This report summarizes Arconic's Intermediate Design Report (IDR), which outlines the design of the habitat reconstruction in the Grasse River. From the introduction:

> "The objective of this Grasse River Superfund Site Habitat Reconstruction Plan, as outlined in the Record of Decision (ROD) (U.S. Environmental Protection Agency [USEPA], April 2013), is to identify impacts to habitat and species from the remedy, identify habitat re-establishment goals, provide design specifications for habitat recovery, and provide the scope for monitoring of habitat recovery. This plan considers habitat and species management goals such as those stated in the New York State Comprehensive Wildlife Conservation Strategy NYSDEC 2005)."

This report provides a project overview (site preparations, dredging, backfilling, equipment summary, etc.), details the existing habitat conditions, describes possible effects of the remediation on the habitat and biota, describes the species considerations for reconstruction (for fish, mussels, etc.), describes the habitat reconstruction designs for different parts of the river and the habitat features/plantings that will be added and when, identifies the monitoring that will occur, and describes an adaptive management plan.

Site preparations.–Site preparations include the construction of a large staging area being built upstream of the Route 131 bridge. Shorelines will be cleared for equipment to operate, and the abandoned gas pipeline will be cut, capped, and removed (work will not block the width of the river at any time to allow biota to pass). Outfall 001 will be relocated and remediated, including onshore excavation.

Dredging.–The IDR contains extensive information about the dredge prism (the horizontal and vertical extents of dredging) and PCB delineation, very little of which is referenced in this overview document. Nearshore dredging will occur over 24 acres. The dredge plan was created to take into account where equipment could be used, dredgability of sediment, the necessity for "access dredging" to get to the spot that needs to be dredged, and recreational boating. Dredging will not take place across the width of the river to allow fish passage and will start after the Lake Sturgeon spawning season. Resuspension during dredging is thought to be minimal based on pilot studies, and additional precautions other than those stated in the 'best management practices' (BMPs) section in the IDR will not be used. These BMPs are not described in this overview. Nearshore backfilling will be performed after dredging and they will attempt to refill these areas with original-grade sediment. It is expected that backfilling will increase turbidity temporarily but will not otherwise affect water quality. Sequencing of backfill will depend on post-dredge verification and approvals. Backfill types will include "Type A": Slope <5:1 (Source BS-5 or BS-10) sand 2–4% OC (organic content); "Type B": Slope 3:1–5:1 (BS-11 mixed with gravel) Sand/gravel with OC of 2–4%; and "Type C": Slope > 3.1 (Cobble/Gravel) <4".

Main channel capping.–The armored cap will be placed at transects T1–21 (~56 acres, 25" thick cap), and unarmored cap will be placed at transects T21–T72 (226 acres, 12" thick cap). The armored cap will consist of: a 6" chemical isolation layer, a 6" gravel filter layer, and 13" of

3–10” gravel/cobbles (median size = 6”), consistent with material used to construct sturgeon spawning beds in other areas (although they note that it isn’t a guarantee even if the flow velocities and substrate are there). From transects T6–T21 there will be a habitat layer that will fill the interstitial space between the cobbles plus an additional 1–2” of material on top. The unarmored cap will have 6” of sand/granulated carbon and 1% organic content, topped with 6” of sand with 1% organic carbon. The habitat layers are meant to act as habitat for recolonizing benthos and the source of the organic matter to be included is not yet determined.

Bioturbation and capping.– Arconic previously found a bioturbation depth of 5 cm in the Grasse River but chose the EPA’s guidance of 10 cm deep. Arconic sent out a memo in 2009 providing lines of evidence that the depth of the bioturbation layer in the Grasse River is only 3” based on field studies of sediment scour, radiochemical tracer analysis of sediment, and benthic community surveys, reviews of life history of burrowing taxa, and studies of the physical and chemical properties of sediments. They cite studies that show that most bioturbation occurs in the upper 10 cm of sediment, but also cite a study that showed that 70% of burrowed mussels were within the first 10 cm of sediment, and no mussels were found >20 cm deep. Another study found mussels burrowed 6.3–10 cm deep. Arconic states that mussels rarely burrow deeper than their shell length, and in the Grasse River the valve lengths of most taxa were <3”, and very few were 5–6”. Listed are a variety of fish species that have the ability to burrow or disturb sediment (American Eel [*Anguilla rostrata*], Burbot [*Lota lota*], Brown Bullhead [*Ameiurus nebulosus*], Common Carp [*Cyprinus carpio*], Freshwater Drum [*Aplodinotus grunniens*], Lake Sturgeon, Smallmouth Bass [*Micropterus dolomieu*], Largemouth Bass [*M. salmoides*], Rock Bass [*Ambloplites rupestris*], White Sucker [*Catostomus commersonii*], and redhorse [*Moxostoma* spp.]), but Arconic states that they will have little influence on bioturbation due to the substrate being used and life histories of the fish. They do not expect bioturbation from plants since the channel area being capped is too deep for most plants to grow. Arconic also expects the depth of the sediment to increase over time with natural sedimentation as seen in the activated carbon pilot study.

*Existing habitat conditions.–*There is not much nearshore area in the Grasse River because the shore trends steeply down to the main channel. Only sections of the river 0–5’ deep have aquatic vegetation, and the main channel is bare (with coarse-fine grain sediments), but there is vegetation overhanging much of the shoreline. There are several emergent wetlands. “Nearshore” was defined as any area with water depths 5’ or less, and these typically extend 25’ from shore. Fines were the most common sediment size, followed by sand. More coarse materials were found upstream than downstream. Nearshore transects were equally vegetated and bare. A total of 59 acres of aquatic vegetation were delineated: when present, aquatic vegetation is dense, and the most common species found were wild celery (*Vallisneria americana*) and pondweed (*Elodea canadensis*), plus a lot of filamentous algae. More than 5 acres of emergent vegetation beds were delineated, containing 189 emergent beds, and were comprised mostly of common bur-reed (*Sparganium eurycarpum*), softstem bulrush (*Schoenoplectus tabernaemontani*), and narrowleaf cattail (*Typha angustifolia*). The majority of large woody debris was found within 3 m of shore, and 90% was in the form of large tree trunks. Undercut banks were found across 2.5% of the shoreline. Shoreline areas next to the proposed dredging sites will need to be regraded to prevent erosion. Plant species in these areas have been catalogued for replanting. A list of culturally important plants to the Saint Regis Mohawk Tribe have been included in the planting list.

Typical water depths in the lower Grasse River are 10–25” due to the deepening of the river in the early 1900s and construction of the Moses-Saunders Power Dam and the Snell Lock. This is in contrast to the middle and upper Grasse River, which are much shallower. In addition, due to the proximity to the mouth, this section of the river is primarily depositional—in the main channel, 79% of sediment was fines. Large woody debris was found at 40% of transects. The main channel is mostly devoid of vegetation except algae.

Here is a summary table from the report of the total amount of habitat within the remediation areas:

Table 3-1. Habitat Features Within Remediation Areas

Habitat	Northern Near Shore	Southern Near Shore	Main Channel Armored Cap	Main Channel Sand Cap
Submerged and Floating Aquatic Vegetation	12.1 acres	9.7 acres	-	-
Wetland/Emergent Vegetation	0.8 acre	0.6 acre	-	-
Bare Substrate	0.5 acre	1.1 acres	-	-
Riparian	575 feet	255 feet	-	-
Main Channel	-	-	56 acres	226 acres

Remediation Effects.–Trees will be trimmed to access the sites and some areas of the shoreline will be regraded to provide “stable post-dredge slopes.” Dredging will take place along the shoreline of the staging area for the bulkhead wall where sediment will be transferred. After the cleanup is complete the bulkhead will be removed, but the boat dock will be left in place. Due to the sequencing of the project, it is likely that few areas of the river will remain unvegetated at a given time. Boulders and rocks in the nearshore will be removed for dredging, but boulders in the main channel will remain in place unless they interfere with construction or the cap. While the water depth in the main channel will decrease due to placement of the cap, the nearshore areas will be returned to pre-dredge grade. 60% of the nearshore area will not be remediated, so effects on nearshore fishes may be minimal.

Lake Sturgeon spawning habitat is not present in the remediation area, but much of the main channel was classified as foraging habitat (90% for juveniles, 85% for adults). The likelihood of Eastern Sand Darter in the area is already low, much of potential habitat will not be altered. Likely eastern pond mussel habitat will not be disturbed, except from transects T1–T6. Mooneye [*Hiodon tergisus*] are anticipated to be upstream of the remediation area, if present at all, and not anticipated to be affected. Benthic organisms will be covered in backfilled sediment, although they will be covered in several lifts and may be able to dig out (although this is unlikely). The area to be covered in a given year will not exceed >25% of Lake Sturgeon foraging areas, and then it is expected that benthos will recolonize the remediated areas fairly quickly. Most of the invertebrates in the target area are collector-gatherers that feed on fine particulate organic matter (FPOM). “For all areas where it is placed, the substrate will be augmented with fines, wood debris, and leaf litter that naturally enters the system.”— They expect that the cobbles to be added at transects T1–T6 could be used as spawning habitat by a variety of fish species.

Reconstruction approach.–Substrate placement is most important, followed by vegetation and habitat features (woody debris, boulders), but they expect that additional sediment and woody debris will be deposited over time.

> "The overall goal of the habitat reconstruction program is to reestablish the structure and function of habitats impacted by the remedy and, where determined to be appropriate and feasible, identify opportunities for improvement such as increasing plant species diversity and/or composition. […] Four primary habitat types were identified for the purposes of the HDA activities and to support habitat reconstruction designs: 1) river bottom; 2) aquatic vegetation; 3) shoreline/riparian; and 4) wetlands. As discussed in the IDR, there are two overall approaches to habitat reconstruction—"in-kind in-place" and "habitat-based." In-kind in-place means that the same type of habitat will be reconstructed to provide the same functions as the impacted habitat, but it does not mean that all components of that habitat will be replicated. The two main habitat types that will be reconstructed in the in-kind in-place approach are aquatic vegetation and wetlands. Areas delineated as aquatic vegetation beds will be reconstructed to pre-dredging elevations and vegetation will be established either through planting or natural recolonization. Wetland areas will also be returned to grade and planted with native wetland species. The areas where in-kind in-place reconstruction is not feasible or applicable will be reconstructed using the habitat-based approach. For these areas, habitat requirements for species or groups of organisms will be used to guide the reconstruction designs. For example, in the main channel, placement of a habitat layer over a portion of the main channel armored cap is planned to support BMIs and mussels. The habitat layer will be augmented over time by ongoing natural sedimentation. A habitat layer is not planned for the remaining (upstream-most) portion of the armored cap from T1 to T6 to avoid eliminating the larger interstitial spaces needed for larval recruitment of fish and use by larger BMIs, such as crayfish."

Plantings.–Plants from un-remediated areas will be used to seed plants in remediated areas. In the Remedial Options Pilot Study (ROPS) plants returned to the remediated area within one year and percent cover was recovered in five years. Wild celery will be planted in 2' centers as founders. Locations for plantings were designated using this criteria: plants were upstream (providing material downstream), downstream (if there wasn't submerged aquatic vegetation upstream), at the upstream edge of dense beds, and next to wetlands. In wetlands, wetland plants will be planted in 2' centers with 2" plugs, and 2% organic matter will be included in the backfill instead of 1%. In the riparian zone, trees will be planted on 12–15' centers. Plantings will take place soon after an area is capped or backfilled, or within the same year.

Habitat recovery monitoring.– Monitoring will include two major performance criteria: 1) the habitat has been reconstructed as designed, and 2) to document vegetation establishment and habitat use post-reconstruction. Monitoring actions for vegetation will include placing quadrats in aquatic/emergent vegetation and monitoring growth/cover/species composition. Mussel surveys (performed by divers) will be performed along 10 transects nearshore and along 10 transects in the main channel. Ponar grabs for benthic invertebrate community analysis will be performed except in the armored cap T1–T6, where they will look for presence/absence. Aris sonar will be used to look for sturgeon—the amount of effort is to be determined. Monitoring will be conducted annually for the first 5 years (except mussels, which they anticipate will take longer to reseed) and will start the year after all construction is finished. Monitoring locations will be finalized post-reconstruction. There are specific benchmarks for vegetation recovery, but none outlined for fish or benthic invertebrates. These are laid out completely in the report, along with planting guides (Appendix B in the reference report). Lastly, they will use an adaptive management approach: 1. monitor, 2. enhance data gathering, 3. implement response actions that will help recovery process, and 4. re-evaluate goals. The report maps of all proposed habitat reconstruction on each part of the river.

Alcoa, 2016. Draft habitat delineation and assessment report. Grasse River study area. 129 pp (without appendices).
From the introduction:

> "This Habitat Delineation and Assessment Report (HDA Report) has been prepared on behalf of Alcoa Inc. (Alcoa) and describes the 2015 field investigations conducted to document the existing habitat conditions in and along the lower Grasse River. All field efforts were performed in accordance with the Habitat Delineation and Assessment Work Plan (HDA Work Plan; Alcoa, August 2015). The scope of the HDA field efforts was developed based on discussions between Alcoa, the United States Environmental Protection Agency (USEPA), the New York State Department of Environmental Conservation (NYSDEC), the National Oceanic and Atmospheric Administration (NOAA), and the St. Regis Mohawk Tribe (SRMT). Per the April 2013 Grasse River Superfund Site Record of Decision (ROD) issued by USEPA to address polychlorinated biphenyls (PCBs) in the Grasse River Study Area (Study Area or Site), the data obtained during the habitat studies will be compiled and evaluated in the HDA Report to support development of the Habitat Reconstruction Plan.
> This HDA Report provides a general description of the nature, type, and extent of the various habitats evaluated as well as a description of any fish and wildlife observations made during the conduct of the work. As requested by USEPA, this report also specifically includes river wide mapping of substrate, field calibration of previous qualitative results, summary of timed events and incidental observations for species of interest, habitat cover types, profiles of existing conditions, and species profiles for the identified state and federally listed threatened and endangered (T&E) species as needed. This report also includes brief summaries of other completed/ ongoing studies including the Lake Sturgeon larval drift study, the Lake Sturgeon radio telemetry study, and the mussel survey. All efforts outlined in the HDA Work Plan (Alcoa, August 2015) were completed from August to October 2015 except for the wetland delineation work. The formal wetlands delineation is planned for 2016 for wetlands identified within the final remedy footprint or in areas that may be impacted by the remedy."

Specifically, this report summarizes the methods and results of the following surveys in the Grasse River: river bottom habitat surveys (grain size and large woody debris (LWD), in nearshore and main channel areas, undercut banks along the shore, and the Remedial Options Pilot Study/ROPS armored cap area), aquatic vegetation surveys (nearshore/main channel, vegetation bed mapping, stem counts, ROPS nearshore vegetation), benthic community surveys (main channel, nearshore), riparian habitat survey, and wildlife observations. Pages 28–34 include threatened and endangered species assessments for a variety of taxa (e.g., Lake Sturgeon, mussels, and other fish and wildlife). There are eight appendices A–H (A. Near Shore and Main Channel Habitat Transect Cross Sections and Plan Views; B. Photolog of Representative Large Woody Debris Above Water; C. Photolog of Undercut Bank Examples; D. Main Channel Transect Habitat Videos; E. Photolog of Riparian Habitat; F. New York Natural Heritage

Program Response and Species List; G. United States Fish and Wildlife Service Response and Species List; H. Species Profiles). There is also one Addendum (see below).

Brief overview of results.–Sediment size varied, fines were most common near shore (70–75%), followed by sand, and there was more coarse material/bare substrate upstream. Few rocks were found above the water surface. Approximately 40–50% of nearshore was bare substrate. In the main channel, fines were also the most common sediment size (79%). Most larger substrates covered in fines. LWD was found in ~50% of nearshore transects (2.4 pieces/transect), ~70% within 3 m of shore and there was less LWD in the main channel (10 pieces of wood total). Most LWD was single trunks/stems (>80%). Undercut banks made up ~2.5% of shoreline distance and were more common upstream than downstream. Vegetation was present at 89% of nearshore plots; 15 plant species were observed. Average percent vegetation cover nearshore ranged from 46 to 57%. Wild celery and pondweed were the most common plant taxa. More plants were found downstream than upstream. No vegetation was found in the main channel (except at T2 which is very shallow, and there were only a few plants). Most nearshore areas in the lower Grasse River have moderate-high densities of aquatic vegetation. A summary of the benthos results is not provided—see the Addendum summary below (Arconic Inc., 2016b). Riparian habitat results are discussed, but are not outlined here as they are out of the scope of this review. Thirty one species of wildlife were observed during surveys (birds, mammals, etc., but no species of concern were observed).

Species profiles.–Species of special concern that could in in the remediation area were identified, and species profiles for some taxa were included here and not in Appendix H. For Lake Sturgeon they state that the Kleinschmidt reports (Kleinschmidt, 2015a, 2016b, 2017) provide all the information needed for sturgeon in the Grasse River. The Fragile Papershell (*Potamilus fragilis*) and Pink Heelsplitter (*Potamilus alatus*) mussels are in the lower reach of the Grasse River (2015 mussel survey), but the other two mussels of concern are upstream. Riverweed (Podostemaceae) was found in the Massena Rapids (upstream) but not in the study area, and Emory's sedge (*Carex emoryi*) was also reported upstream but was not found in the plant assessments performed. Eastern Sand Darter occur upstream and there may be suitable habitat for them between T1–T8. The probability of finding Mooneye is low. Possible wetlands for Blanding's turtle (*Emydoidea blandingii*) will not be affected. Seasonal foraging of Bald Eagles (*Haliaeetus leucocephalus*) may be affected by the remediation but there will be no influence on Northern Harrier (*Circus hudsonius*), Upland Sandpiper (*Bartramia longicauda*), or Northern Long-eared Bats (*Myotis septentrionalis*).

Arconic Inc., 2016a. Draft habitat delineation and assessment report. Appendix H: Species Profiles.

Summary:

> "This section provides information on the potential for threatened and endangered (T&E) species to occur within the project area. The list of T&E species for consideration was developed through consultation with the NYSDEC Natural Heritage Program (NYNHP) for state-listed species and the United States Fish and Wildlife Service (USFWS) for federally-listed species. Consultation with the NYNHP and USFWS is required by Part 182 of New York Environmental Conservation Law and Section 7 of the Endangered Species Act, respectively. These consultations are meant to assist applicants in avoiding adverse impacts to T&E species or habitats, and if necessary, to allow the incidental

> "taking" of T&E species." "Similarly, consultation with the USFWS for federal-listed species was initiated by using their Endangered Species Act consultation website." "For each species listed above, information was evaluated to understand the potential likelihood of the species occurring within the project area, or to be affected by remedial activities. In cases where less Grasse River specific information was known about a particular species, species profiles were developed that summarize relevant habitat, general ecology, and life history information, including an assessment of life cycle time period requirements necessary for certain species (Appendix H). As such, specific species profiles were developed for all of the species listed above with the exception of Lake Sturgeon, freshwater mussels, riverweed, Emory's sedge, and waterfowl winter concentration area. For these, much is either known about them within the vicinity of, and in, the project area/or site-specific studies have been or are being conducted."

List of species profiled in Appendix H: Eastern Sand Darter, Mooneye, Blanding's turtle, Bald Eagle, Northern Harrier, Upland Sandpiper, and Northern Long-eared Bat. For each taxon they detail the distribution/range, life history, home range, and habitat preferences. Each species has a summary table of these characteristics.

Arconic Inc., 2016b. Draft habitat delineation and assessment report. Addendum No. 1. Grasse River study area.
Introduction:

> "This Habitat Delineation and Assessment Report Addendum No. 1 (HDA Report Addendum No. 1) has been prepared on behalf of Arconic Inc. […] and describes the 2016 field investigations (field efforts and results) conducted to supplement the habitat data set for the lower Grasse River. The 2016 field investigations included wetland delineation, shoreline/riparian habitat transect surveys, and emergent vegetation bed delineation. All 2016 field efforts were performed in accordance with the Habitat Delineation and Assessment Work Plan Addendum No. 1 (HDA Work Plan Addendum No. 1; Alcoa, August 2016). […] The results of the 2015 field investigations were provided in the Draft Habitat Delineation Report (Draft HDA Report; Alcoa, March 2016), except for the benthic invertebrate community data as the samples were being processed by the laboratory at the time of report preparation. The results from the 2015 benthic invertebrate sampling are included herein. […] This document is an addendum to the HDA Report and provides the remaining habitat data necessary to support the Habitat Reconstruction Plan as well as ongoing remedial design efforts. Details pertaining to the site description, study goals and data quality objectives (DQOs), summary of previous habitat studies, and the 2015 work are provided in the HDA Report (Alcoa, March 2016). The specific DQOs that guided the habitat data collection and evaluation are listed below. […] This HDA Report Addendum No. 1 provides a general description of the nature, type, and extent of the specific habitats evaluated (including associated habitat mapping), as well as a description of any fish and wildlife observations made during the conduct of the work."

Specifically, this report provides all of the benthic invertebrate (benthos) data collected in 2015 and 2016 habitat delineation/assessment monitoring efforts and data, and Remedial Options Pilot

Study (ROPS) main channel armored cap measurement data. There are six appendices: A–C: wetlands/soil survey mapping; D: underwater video coverage along the ROPS armored cap; E: shoreline/riparian habitat transect data; F: photos of the emergent vegetation beds.

Benthos results.–The community is typical of those found on fine-grain substrates. Nearshore, dipterans were most common (46–53% of the community) and were 19% of main-channel community. The most common taxa in the main channel were oligochaetes and polychaetes (~35%). Biomass was higher nearshore (~140 mg) than in the main channel (105 mg) and diversity was also higher nearshore. Main-channel benthos had higher tolerance values (7.5) than nearshore (6.9–7), but not by much. Sixty-six percent of nearshore and 84% of main-channel benthos were gatherers (deposit feeders) and most were burrowers. The only organism deemed acceptable for PCB testing was the Eastern Elliptio Mussel (*Elliptio complanata*).

Wetland delineation results.–Maps from the National Wetlands Inventory, US Geological Survey, soil surveys of St. Lawrence County, and NYSDEC were used to delineate wetlands and there was also field delineation performed according to a US Army Corps of Engineers manual. Thirty one wetland areas were identified within the remediation area (fringing wetlands, forested/shrub/scrub wetlands, and emergent/wet meadows).

Remedial Options Pilot Study results.–Material over the cap was ~1" on average (0.3–2.9"; not counting sediment wedged between rocks). Current sedimentation rates estimated to be 0.2–0.7 cm/year.

Shoreline habitat.–Shoreline habitat results and emergent vegetation data are summarized and presented (but are out of the scope of this review).

Bonner, J.S., Fuller, C.B., Islam, M.S., 2015. Characterization of sturgeon spawning habitat on the Grasse and Raquette rivers, New York. Final Report. Clarkson University, Potsdam, NY. 259 pgs.

The goal of this study was to measure a suite of environmental variables (water quality, hydrology, meteorology) at two sites thought to be suitable for Lake Sturgeon spawning in the Grasse and Raquette rivers, New York during 2014 and 2015. The report provides an overview of the data collected, but beyond summaries the data have not been analyzed. The study was based on a quality assurance plan created in 2013 that outlined study goals and objectives. The Raquette River site was 4.2 km upstream from the confluence with the Saint Lawrence River (hereafter St. Lawrence River) at the Akwesasne boundary, and the Grasse River site was 37 km upstream from the confluence with the St. Lawrence River at Chamberlin Corners. A Real Time Hydrologic Monitoring Station (RTHS) measured water quality (water temperature, dissolved oxygen, and pH) and a meteorological station measured air temperature, barometric pressure precipitation, wind speed and direction, and relative humidity over seven months from spring to fall 2014 at each site. During low and high-water events (as identified by nearby US Geological Survey [USGS] gaging stations) discharge and water velocity profiles were measured along 20–21 cross-sectional transects in 2014 (10 at Grasse River, 11 at Raquette River) and 2015 (10 at both sites, downstream of 2014 transects). The water velocity profiles were measured using a Teledyne RDI Stream Pro Acoustic Doppler Current Profiler (ADCP; 2400 kHz) or HACH HF 950 if the water depth was below 0.2 m. The Stream Pro was better for depths 0.1–2 m. The ADCP was deployed using a tag line across the river. Lastly, a subcontractor measured bathymetry at both sites using a Reson 215 dual frequency single-beam echo sounder with HYPACK hydrographic software deployed from 15-ft boat.

Grasse River Results.–The Grasse River experiences highly variable flow and the flow is not regulated. The riverbed was characterized by shallow riffles and deeper pools, with substrates of bed rock and large rocks. There were few aquatic plants. In 2014, the mean water depths at each transect ranged from 0.41 to 6.7 m during high flow, and 0.17–0.54 during low flow. In 2015, the mean water depths at each transect ranged from 0.24–0.75 m during high flow, and 0.12–0.52 m during low flow. The discharges observed at the site were always higher than those observed at the nearby USGS stations (1.03–1.23 times). In 2014, a high flow event (52 m^3/s) was measured June 17–18 with water velocities 0.7–1 m/s (mean 0.85 m/s). A low-flow event (8.6 m^3/s) was measured July 24–25 with water velocities 0.2–0.5 m/s (mean 0.36 m/s). In 2015, a high flow event (19.1 m^3/s) was measured September 14 with water velocities 0.18–0.7 m/s (mean 0.33 m/s). A low-flow event (5.8 m^3/s) was measured August 6 with water velocities 0.07–0.17 m/s (mean 0.17 m/s). Overall, water velocities were ~0.5–1 m/s at high flow/shallow transects, and in low flow were <0.5 m/s.

Raquette River results.– The Raquette River has flows managed by Brookfield Renewable and has permits to maintain a minimum flow of 16.1 m^3/s and tries to maintain flows >25.5 m^3/s. There were no shallow riffle areas in the area studied. In 2014, the mean water depths at each transect ranged from 1.21–1.48 m during high flow, and 0.57–1.15 during low flow. In 2015, the mean water depths at each transect ranged from 0.85–1.32 m during high flow, and 0.8–1.2 m during low flow. The discharges observed at the site were often higher than those observed at the nearby USGS stations (1.11–1.89 times), except when measured flow was 58% of that observed at the USGS gage (low flow event in 2014). In 2014, a high flow event (121 m^3/s) was partially measured July 21 with water velocities 1.1–1.2 m/s (mean 1.12 m/s). A low-flow event (34 m^3/s) was measured August 7–8 with water velocities 0.29-0.68 m/s (mean 0.42 m/s). Another high flow event (53 m^3/s) was fully measured on October 19, 2014 with water velocities 0.48–0.82 m/s (mean 0.61 m/s). In 2015, a high flow event (86 m^3/s) was measured July 15 with water velocities 0.75–1.13 m/s (mean 0.95 m/s). A low-flow event (30 m^3/s) was measured July 28 with water velocities 0.34–0.67 m/s (mean 0.51 m/s). Overall, maximum velocities ranged from ~1 m/s in low flow to ~2 m/s during high flow.

Overall results.–Dissolved oxygen sometimes dropped <7 mg/L, but >7.5 is best for Lake Sturgeon eggs; low dissolved oxygen may be a stressor on egg development in these areas. Water temperatures also reached up to 25°C, which could be too hot for egg development. Overall, the study concluded that these areas have adequate water velocities and depths required for Lake Sturgeon spawning. Many graphs of each environmental variable, including velocity cross sections, are in the report.

Attached memo.–A memo, "Clarification of Characterization of Sturgeon Spawning Habitat on the Grasse and Raquette Rivers, New York Final Report (October 2015)", was attached to this report and was released by the Saint Regis Mohawk Tribe. It stated that the data in the report needs to be further analyzed using a hydrodynamic model to "evaluate shear stress as a function of flow." They note that sites where velocity data were collected in 2014 did not match the targeted areas outlined in the 2013 quality assurance plan, so sites were sampled again in 2015 to remedy this. They also note that 2015 was a low-flow year in general, and that the 'high flow event' (19.1 m^3/s) in 2015 is not representative of high flows in the Grasse River, because USGS annual discharge is typically 33 m^3/s and is much lower than extreme high flows identified by Alcoa (330–483 m^3/s). Lastly, they note that anyone using this data should review the river dynamics of ice jams 2009 report by Alcoa and consider the shear stress observed during extreme flow events.

Bouchaert, E.K., Auer, N.A., Roseman, E.F., Boase, J., 2014. Verifying success of artificial spawning reefs in the St. Clair-Detroit River System for Lake Sturgeon (*Acipenser fulvescens* Rafinesque, 1817). Journal of Applied Ichthyology 30, 1393–1401.
Abstract:

> "Lake Sturgeon (*Acipenser fulvescens*) were historically abundant in the St. Clair – Detroit River System (SCDRS), a 160 km river/channel network. In the SCDRS, Lake Sturgeon populations have been negatively affected by the loss/degradation of natural spawning habitat. To address habitat loss for Lake Sturgeon and other species, efforts are underway to restore spawning substrate by constructing artificial reefs. The main objective of this study was to conduct post-construction monitoring of Lake Sturgeon egg deposition and larval emergence near two of these artificial reefs: Fighting Island Reef (FIR) in the Detroit River, and Middle Channel Reef in the St. Clair River. An additional site in the St. Clair River where Lake Sturgeon spawn on a coal clinker bed was also investigated. From 2010 to 2012, viable eggs and larvae were collected from all of these reefs, indicating that conditions are suitable for egg deposition, incubation, and larval emergence. In the St. Clair River, the results indicate the likelihood of other spawning sites upstream of these artificial reef sites."

Carlson, D.M., 1999. Fishery survey of the Grasse River data summary. Unpublished report. New York Department of Environmental Conservation. Region 6, 14 pgs.

This report describes the history of fisheries surveys that have taken place in the Grasse River and later details results from a study performed in 1998. The first fish survey began in 1930 and small surveys occurred periodically until the first comprehensive survey took place from 1987–1988 at 22 sites finding 19 species of fish. Sturgeon were first found in surveys in 1988 (two juveniles) and were the focus of additional surveys throughout the 1990s. Spawning was observed on May 1, 1992 at Madrid Dam, and eggs were subsequently found May 6 and 7. Stones were added to the spawning site to add spawning habitat but were moved by currents and provided "little benefit." In 1992, no sturgeon were found during June/July surveys at Massena. From 1993–1997 several sturgeon were captured in the Grasse, but in 1998 an extensive netting effort (107 nets) captured 51 sturgeon. In 1993, 2000 hatchery fingerlings were stocked in the Grasse but there was no evidence of survival. The study performed by Carlson used electrofishing, gill nets, and seines to catalog the fish species of the Grasse at 53 sites. The most common fish were smallmouth bass and rock bass, and 44 total species were observed. When added to the results of a previous survey, a total of 54 fish species have been found in the Grasse River, and there was high species richness compared to other streams in the region. The Grasse supports popular walleye and muskellunge fisheries. Five rare taxa were found in the lower basin: eastern sand darter (from Massena to Canton), bridle shiner, blacknose shiner, American brook lamprey, and Lake Sturgeon. Carlson categorized Lake Sturgeon as "vulnerable" but "no longer threatened." Most of the sturgeon captured were 550–750 mm in length, but some were >1,300 mm. The report contains tables of catch per unit effort (CPUE) of each fish species captured.

COSEWIC, 2006. Assessment and update status report on the Lake Sturgeon *Acipenser fulvescens* in Canada. Ottawa, Ontario.

COSEWIC is the Committee on the Status of Endangered Wildlife in Canada, and "COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk." In 2006, COSEWIC reassessed the status of eight Lake Sturgeon populations or "designatable units" in Canada, and this report was finalized post-reassessment. This report consists primarily of a lengthy review of sturgeon life history and ecology, details their current status, and provides a technical summary of Lake Sturgeon populations in each designatable unit. There is a description of how units were identified (based on genetics, land is biogeographically distinct, etc.). A population must consist of 500 individuals to maintain genetic diversity. The unit that aligns with the Grasse River population of interest is DU8 – "Great Lakes – Upper St. Lawrence."

History of the DU8 unit.–In 1879, Canadian waters of the Great Lakes were opened to commercial Lake Sturgeon fishing. Catches of Lake Sturgeon in the St. Lawrence River were consistent from 1920–1984, which lasted much longer than other places where Lake Sturgeon fisheries collapsed. Overexploitation may not have started until the 1970s, and from 1987–1991 new management plans were introduced to limit catches and protect spawning fish.

Status of DU8 unit.–In the St. Lawrence River there are currently 14 extant Lake Sturgeon populations (12 small, 2 large). Spawning occurs at six sites, four of which have spawning runs with <1,000 fish, but more are found in Saint-Maurice (~1,250) and des Prairies (~7,000) rivers. Lake Sturgeon in the DU8 are still experiencing population declines due to contaminants and overexploitation and only three populations may have >1,000 adults. In DU8, Lake Sturgeon are found in <70 locations, and their extent of occurrence Is ~600,000 km^2. The number of mature fish is unknown, and there was a dramatic decline in numbers two to three generations prior to the report. Not all populations in the DU8 are declining (but they are in the St. Lawrence River).

Management.–There is a summary of limiting factors and threats to Lake Sturgeon throughout Canada, and a summary of their special significance. There is a summary of current protections related to Lake Sturgeon. Management of Lake Sturgeon and its habitat are under the Fisheries Act (regulated by Department of Fisheries and Oceans) but the provinces regulate catch. Sport fishing for Lake Sturgeon is not allowed in the St. Lawrence River, but there is limited commercial harvest. Quebec has an additional fisheries regulation, the "Environmental Quality Act" that protects habitat. Fish in the Quebec part of the St. Lawrence River have been managed/studied for ~25 years, and efforts have been made to protect and improve habitat and reduce water pollution.

Fidler, C., 2017. Remedial Action Plan Status Update. St. Lawrence River AOC at Massena/ Akwesasne. New York State Department of Environmental Conservation and St. Regis Mohawk Tribe.

This document outlines the status of the Remedial Action Plan (RAP) and the Beneficial Use Impairments (BUIs) in the St. Lawrence Area of Concern (AOC). It is primarily in the form of a large table with each BUI and its removal criteria and removal progress. Many of the BUI removal actions are dependent on the Grasse River remediation. This is an updated version of the document that considers the cultural use of resources. There are six primary BUIs in the AOC: restrictions on fish and wildlife consumption, degradation of fish and wildlife populations, fish tumors or other deformities, bird/animal deformities or reproductive problems, degradation of benthos, and loss of fish and wildlife habitat, most of which have target dates for removal of "2024+" and are contingent of the Grasse River remediation and post-remediation monitoring.

Levels of PCBs in fish are tested annually in the Grasse River, and will continue to be tested post-remediation, but there are also fish consumption advisories in the bay/cove near the Franklin/St. Lawrence county line. The BUI for degradation of fish/wildlife populations may be removed once PCBs are as low as in other areas, fish/wildlife species richness/diversity in the AOC are the same as other areas, and sentinel species (Bald Eagle, American Mink [*Neogale vison*], Lake Sturgeon, otter [Lutrinae]) are present/reproducing in the AOC. At the time of writing, the Remedial Action Committee (RAC) was working on a habitat and population strategy and was planning future monitoring/assessment projects. The fish tumor BUI is likely to be removed based on completed field work but is also contingent on post-Grasse River remediation monitoring. Similarly, the bird/animal deformities BUI has a target removal date of 2020 and there are reports of adequate mussel and turtle recruitment, but turtle deformities at birth are unknown and furbearer reports are needed. The degradation of benthos BUI has a removal date of 2024+ and is contingent on the Grasse River remediation and while mussel populations in the AOC are doing well and exhibit little toxicity, the mussels will need to be reseeded in the Grasse River post-remediation. The RAC is still working on the strategy for the habitat BUI, but there are vegetation and mapping surveys occurring. They aim to "conduct habitat enhancement projects" although no details are provided. The removal for this BUI is heavily dependent on the Grasse River remediation and reconstruction.

Golder Associates Ltd, 2011. Recovery strategy for Lake Sturgeon (*Acipenser fulvescens*) – Northwestern Ontario, Great Lakes-Upper St. Lawrence River and Southern Hudson Bay-James Bay populations in Ontario., in: Ministry of Natural Resources, Ontario Recovery Strategy Series. Peterborough, Ontario. 86 pgs.
About the Ontario Recovery Strategy Series:

> "This series presents the collection of recovery strategies that are prepared or adopted as advice to the Province of Ontario on the recommended approach to recover species at risk. The Province ensures the preparation of recovery strategies to meet its commitments to recover species at risk under the Endangered Species Act (ESA) and the Accord for the Protection of Species at Risk in Canada." Further, "Recovery strategies are required to be prepared for endangered and threatened species within one or two years respectively of the species being added to the Species at Risk in Ontario list. There is a transition period of five years (until June 30, 2013) to develop recovery strategies for those species listed as endangered or
> threatened in the schedules of the ESA. Nine months after the completion of a recovery strategy a government response statement will be published which summarizes the actions that the Government of Ontario intends to take in response to the strategy."

Executive summary:

> "[…] Lake Sturgeon currently inhabit at least 229 waters (128 lakes and reservoirs and 101 rivers) in Ontario. The Committee on the Status of Species at Risk in Ontario (COSSARO) has assigned population status in three regions of Ontario. The Northwestern Ontario population and the Great Lakes-Upper St. Lawrence River population of Lake Sturgeon are classified as threatened. The Hudson Bay-James Bay population is classified as special concern. The recovery goal for Lake Sturgeon in

> Ontario is to maintain existing Lake Sturgeon populations throughout their current range and where feasible, to restore, rehabilitate or reestablish, self-sustaining Lake Sturgeon populations which are viable in the long term within their current habitat and/or within habitats they have historically occupied, in a manner consistent with maintaining ecosystem integrity and function. The main objectives to achieving protection and recovery are to:
> 1. protect or increase extant Lake Sturgeon populations at an abundance commensurate with the capacity of their habitat to support them and the existing fish community;
> 2. maintain, enhance and, where feasible, restore habitat in order to support Lake Sturgeon;
> 3. restore Lake Sturgeon populations in locations where they have become extirpated, where feasible and where functional habitat exists;
> 4. develop local scale Lake Sturgeon management strategies;
> 5. increase public awareness of the cultural and ecological significance and uniqueness of Lake Sturgeon and the importance of maintaining, enhancing and restoring Lake Sturgeon populations; and
> 6. address knowledge gaps to enable and enhance protection, conservation and recovery efforts.
> It is recommended that the area prescribed as habitat in the habitat regulation protect important habitat features for the Northwestern Ontario and the Great Lakes-Upper St. Lawrence River populations of Lake Sturgeon. Important habitat features include spawning areas, nursery areas, overwintering areas, staging areas and the migration corridors connecting them. […]"

This report provides an overview of Lake Sturgeon life history, describes how the Canadian management/recovery units were designated, outlines population trends/trajectories in each unit, identifies threats/barriers to recovery, describes recovery strategy and actions already completed/underway, and has many tables ranking the recommended recovery actions in terms of timeline and priority level. At the end there is rationale for developing a "habitat regulation," which is "a legal instrument that prescribes an area that will be protected as the habitat of the species. The recommendation provided below by the recovery strategy authors will be one of many sources considered by the Minister of Natural Resources when developing the habitat regulation for this species."

Jock, J.L., 2017. Lake Sturgeon (*Acipenser fulvescens*) egg trap study: spawning presence/absence at Chamberlain Corners riffle, Chase Mills, NY, Grasse River. Prepared by Saint Regis Mohawk Tribe Environment Division for U.S. Environmental Protection Agency. No. GL-97221410. Akwesasne, New York.
Project background:

> "Lake Sturgeon spawning habitat characterization studies 2014-2015 undertaken by Saint Regis Mohawk Tribe Environment Division (SRMTED) demonstrated the first riffle on the Raquette River downstream the Railroad bridge and the riffle downstream the Chamberlain Corners bridge (Grasse River) were of suitable substrate, velocity, and depths for Lake Sturgeon spawning (Bonner et al., 2015). These results lend to the plausibility that these riffle areas may make ideal candidate sites for habitat enhancement

> (i.e. spawning reef creation) by placing optimal sized stone (5-10 cm in diameter) as supplemental habitat material in these areas for Lake Sturgeon spawning. SRMTED met with NYSDEC in January 2016 to discuss permitting needs for engineering design and construction, and it was expressed it would be prudent to conduct a biological field study to determine if Lake Sturgeon are already using this habitat as is prior to moving forward with a proposal to modify. Therefore, to proactively gather data to assist in answering this question prior to advancement of applying for a Joint Application Permit Form to NYSDEC and USACE to pursue an excavation or placement of fill in navigable waters in NYS, SRMT proposed the 2016 Egg Trap Study. The objective of this study was to collect environmental data and document any Lake Sturgeon use of the riffle area downstream the CR 44 bridge at Chamberlain Corners in the township of Chase Mills, NY. This objective was achieved by documenting presence/absence of Lake Sturgeon and Lake Sturgeon egg deposition in this study area. Due to the intensive labor investment expected for thorough spatial and temporal representation of 2016 optimal spawning habitat and water temperatures in any of the targeted riffle areas, only one of the riffles (Chamberlain Corners riffle) was proposed and selected for further 2016 field study."

Methods.– They started checking water temperatures 4 April 2016 and deployed egg mats prior to when temperatures reached 8°C. Egg mats were left in the river until water temperatures were at a consecutive 3-day average of 18°C (40 days total). Twenty egg mat gangs (each with 4 furnace filter-covered cement blocks) were placed and checked every 48 hours at first, then twice a week later in the season. Water depth was 30 cm and minimum water velocity was 0.3 m/s.

Results.–No Lake Sturgeon eggs were found, only sucker eggs. One >1-m-long adult was observed and two possible adults were seen April 23 and May 1, 2016. Most fish eggs were found on May 3. The water velocities observed may be too low for spawning (0.1–0.3 m/s) and some of the egg mats experienced sedimentation.

Jock, J.L., Wilkins, J.H., Sunday, E., Skidders, T., Adams, A., 2017. Spring 2017 manual tracking of Lake Sturgeon (*Acipenser fulvescens*) in the Grasse River, NY using radio telemetry. Prepared by Saint Regis Mohawk Tribe Environment Division for U.S. Environmental Protection Agency. No. GL-97221410. Akwesasne, NY. 22 pgs.
From introduction:

> "In 2015-2016, a radio telemetry study was conducted on Lake Sturgeon in the lower Grasse River to understand Lake Sturgeon movement in the Grasse River Superfund Site Study Area ('Superfund Study Area'). This study was designed and conducted by the primary responsible party (PRP), Alcoa, Inc. (now Arconic) and their consultants, with all work plans reviewed and approved by U.S. Environmental Protection Agency (USEPA), New York State Department of Environmental Conservation (NYSDEC), and Saint Regis Mohawk Tribe Environment Division (SRMTED). To monitor Lake Sturgeon movement in the lower Grasse River, 30 adult (>100 cm in length) and 30 juvenile (20-100cm in length) Lake Sturgeon were collected and received a unique coded internal radio tag for individual fish identification and tracking. All fish were implanted with radio tags in summer 2015, and stationary and manual tracking was conducted June 2015-June 2016. The sturgeon were collected from approximately 16 river miles from the

> confluence of the river with the St. Lawrence River to the Louisville Bridge on the Grasse River (Kleinschmidt 2017). […] This work to track and document Lake Sturgeon movement in the lower Grasse River included a specific 2016 spring manual tracking effort. […] To monitor 2016 spring spawning Lake Sturgeon movement in the Grasse River, manual tracking was conducted by Alcoa's team at designated observation points […] SRMTED staff conducted all 2017 spring manual tracking of Lake Sturgeon in the Grasse River following methodology outlined by Alcoa's team in 2016. Primary objective of collecting data was to obtain additional information on Lake Sturgeon spawning locations, spawning dates, and frequency in the Grasse River, as part of the AOC using previously radio tagged Lake Sturgeon (n=60). […] Manual tracking and fish observations were conducted three times per week (Monday, Wednesday, and Friday) at the footbridge, breached weir, Main Street bridge, Louisville bridge, Chase Mills bridge, Chamberlain Corners (CR44) bridge, and Madrid bridge to determine if fish, especially radio tagged Lake Sturgeon, were present at these locations in 2017."

Results.–Lake Sturgeon spawning behavior was observed at Massena Rapids in the Grasse River on April 15 and 17, 2017 (4–6 Lake Sturgeon). One was confirmed as a tagged adult (17 years old). Lake Sturgeon activity was concentrated mostly near the breached weir, and Lake Sturgeon were consistently found there with radio trackers from April 14–28, 2017. None were ever relocated at Chase Mills, Chamberlin Corners, or Madrid, although one un-tagged Lake Sturgeon was observed at Chase Mills and Madrid. Lake Sturgeon were observed before any significant numbers of suckers were found breeding in the Grasse River, but usually the opposite is true.

Jock, J.L., Wilkins, J.H., Tarbell, B., 2018. 2012 Reconnaissance of riffles in the Grasse, Raquette, and St. Regis river tributaries for Lake Sturgeon spawning enhancement monitoring. Prepared by Saint Regis Mohawk Tribe Environment Division. Revis. Final. 33 pgs. Akwesasne, New York.

This report summarizes a 2012 study performed by Saint Regis Mohawk Tribe (SRMT) staff that identified and characterized riffles that may be possible spawning habitat for Lake Sturgeon in the Grasse, Raquette, and Saint Regis (hereafter St. Regis) rivers (NY) downstream of the first barrier impassible to Lake Sturgeon. Sites were identified/characterized to find candidates for possible habitat enhancement. Prior to field work, possible riffles were found using Google Earth imagery, and then were visited to assess the size and depth of the riffle, the composition of the substrate, presence of algae/vegetation/zebra mussels (*Dreissena polymorpha*), and site accessibility. In total there were 11 riffles that met criteria for potential Lake Sturgeon spawning habitat. In the Grasse River there were six potential spawning areas (mostly bedrock with some cobbles and boulders, and some deep pools): the footbridge to Massena Power Canal, the breached weir to Parker Avenue Bridge (Massena), Louisville Bridge, Chase Mills, Chamberlain Corners, and Madrid Dam. In the Raquette River there were three possible spawning areas/riffles: Railroad Bridge, Route 420 Bridge, and Raymondville Dam. In the St. Regis River, there were two possible locations: Hogansburg Dam and Brasher Center Bridge. There were no observations of zebra mussels in any of the riffles. Two sites were identified for further substrate/hydrodynamic assessment: Chamberlin Corners (Grasse River) and the Railroad Bridge (Raquette River).

Johnson, J.H., LaPan, S.R., Klindt, R.M., Schiavone, A., 2006. Lake Sturgeon spawning on artificial habitat in the St Lawrence River. Journal of Applied Ichthyology 22, 465–470.
Abstract:

> "In 1996, Lake Sturgeon (*Acipenser fulvescens*) spawning was documented for the third consecutive year on an artificially placed gravel bed in the St Lawrence River. Two distinct spawning periods were observed in 1996. Spawning initially commenced on 17 June, when water temperature reached 15C. A second spawning event was documented from 28 June to 1 July (16°C). Lake Sturgeon egg densities were monitored in three transects on egg trays, on the gravel surface, and within interstitial spaces in the gravel. Counts of developing eggs in the gravel bed during both spawning periods were used to estimate a total of 275, 000 eggs on the study area (0.075 ha). Average egg density was highest in the transect with the highest water velocities. Lake Sturgeon fry were first observed in the gravel on 24 June (15.5°C), and first emergence from the gravel was documented on 28 June. Hatching following the second spawning event commenced on 3 July. Based on assessment of average embryo viability (61.6%) and egg-to emergent fry survival (17.6%) an estimate of about 171,000 sturgeon eggs hatched, producing over 49,000 emergent fry. Current velocity, substrate particle size, depth of substrate, and maintenance of sediment-free interstitial spaces are important considerations in planning future spawning habitat enhancement projects."

Kerr, S.J., Davison, M.J., Funnell, E., 2011. A review of Lake Sturgeon habitat requirements and strategies to protect and enhance sturgeon habitat. Ontario Ministry of Natural Resources. Fisheries Policy Section, Biodiversity Branch., Peterborough, Ontario. 58 p. + appendices.
Executive summary:

> "Lake Sturgeon (*Acipenser fulvescens*) have recently been designated by the Committee on the Status of Species at Risk in Ontario (COSSARO) as a threatened species in northwestern Ontario and in the Great Lakes drainage basin. The Lake Sturgeon receives protection under the Endangered Species Act (2007, ESA), which requires that a recovery strategy be developed within two years of a species being listed as threatened. Habitat provisions are to be included in the recovery strategy as well as implementation goals. This report has been prepared to summarize Lake Sturgeon habitat requirements, to provide a synopsis of the impacts various activities may have on Lake Sturgeon habitat, and to review habitat mitigation and enhancement strategies which have been employed in various jurisdictions to date.
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> Lake Sturgeon habitat requirements vary depending on their life stage and the time of year. Sturgeon often make long migrations upstream in rivers to spawn usually below an impassable barrier, such as a waterfall or a dam. Clean, coarse cobble and rubble substrates and a continuing flow of fast water characterize most sturgeon spawning sites. Upon hatching, larval sturgeon drift downstream with the current to shallow bays and slow-moving sections of river having sand or detritus substrates. Juvenile Lake Sturgeon are found in deeper waters, exceeding 9 m, more often than adults. Habitat selection at this life stage is determined by the availability of food. Adult Lake Sturgeon generally prefer relatively shallow (< 2-3 m) habitats with a moderate flow of water. They are

> opportunistic, benthic feeders preferring substrates of sand, gravel and detritus. Lake Sturgeon are seldom associated with aquatic vegetation at any life stage. Adult Lake Sturgeon move to deeper water in lakes and riverine refuge pools during the winter when they are relatively sedentary prior to the spawning season.
>
> The decline in Lake Sturgeon across much of North America has been attributed initially to unregulated fisheries and, more recently, to habitat alteration and destruction notably by pollution, dredging and channelization, and the construction of dams and hydroelectric facilities. Dredging and channelization can alter Lake Sturgeon spawning grounds. Sturgeon have been impacted by many forms of pollution which can disrupt olfactory feeding behavior. Dams and hydroelectric stations can have a negative impact on Lake Sturgeon by fragmenting their habitat, impeding migrations to spawning grounds and, depending on the type of operation, having a negative impact on egg survival and recruitment. Downstream migrants may also be impinged or entrained at hydroelectric plants.
>
> Attempts to resolve some of these habitat impacts have included construction of fish passes at dams, establishing base flows or "run-or-river" regimes at hydroelectric facilities, creation or enhancement of spawning areas, use of downstream guidance and diversion structures, and improvements to water quality. There has been some success with constructing artificial spawning grounds for Lake Sturgeon. Sturgeon have also been shown to display a positive response to improvements in water quality and "run-of-river" hydrologic regimes at dams and power stations. The ability to design a fish pass suitable for fish with the body size/shape and swimming capabilities of Lake Sturgeon has proven difficult, however, and further research is required in this area. Many sturgeon populations are also impacted by "peaking" operations at hydroelectric facilities and the issue of facilitating downstream passage over artificial barriers also needs to be resolved.
>
> The impacts of dams, hydroelectric facilities, and other anthropogenic activities pose significant threats to Lake Sturgeon in Ontario. A recovery strategy for Lake Sturgeon in Ontario is currently being developed to provide science-based recommendations on the protection and recovery of this species. Following completion of the recovery strategy under the Endangered Species Act (2007), a government response statement will be developed summarizing the Government of Ontario's intended actions and priorities in response to the recovery strategy."

Kleinschmidt, 2017. Final Report. Monitoring Lake Sturgeon movement in the lower Grasse River, New York, using radio telemetry. Prepared for Alcoa Inc. Pittsfield, Maine. 186 pgs.

This report details findings from a 2015–2016 Lake Sturgeon radio telemetry study in the Grasse River that was performed in accordance with the USEPA and Alcoa. From the introduction:

> "The objective of this radio telemetry study was to quantitatively describe the spatial and temporal movement of adult and sub-adult (i.e., juvenile) Lake Sturgeon within and through the lower Grasse River from June 2015 through June 2016 through use of surgically implanted radio transmitters. The study design was approved in collaboration and consultation with the USEPA, New York State Department of Environmental Conservation (NYSDEC), and Saint Regis Mohawk Tribe (SRMT). Although the study

> focus was on the lower Grasse River, radio tagging and monitoring of Lake Sturgeon was also conducted in the upstream areas (i.e., the middle reach) to evaluate any subsequent movement of these Lake Sturgeon throughout the year into the remediation area. This study provides information which will allow Alcoa to assess the potential effects of lower Grasse River remediation on Lake Sturgeon."

Methods.–Ten fixed receivers were placed along the river to determine Lake Sturgeon movement, the first of which was placed at river kilometer (rkm) 1 (transect T70) to monitor egress to the St. Lawrence River, and the last at rkm 11 (T1) to monitor egress to the middle Grasse River. Fish were collected for tagging using gill nets and baited trotlines. Fish >100 cm were considered adults, and clips from pectoral fin rays were taken for aging. In the middle reach 116 Lake Sturgeon (17 adults, 94 juveniles) were collected from 83 locations, and 15 adults and 15 juveniles were tagged with radio transmitters. In the lower reach 40 Lake Sturgeon (16 adults, 22 juveniles, 2 recaptures) were collected, and 15 adults and 15 juveniles were tagged with radio transmitters. While the stationary receivers were used to collect most movement data, 17 manual tracking surveys were performed at several accessible spots along the river.

Results.– Juvenile and adult Lake Sturgeon were present in the lower Grasse River all year. Three primary movements included: moving throughout the lower Grasse River, leaving the study system to the St. Lawrence River and never returning to the Grasse River, and traveling to the St. Lawrence River and returning to the Grasse River. Eighty percent of fish tagged in the middle river stayed there—some of the ones that left went through the lower Grasse River to the St. Lawrence River. Four of the middle river fish went to the Massena Rapids area in spring then went back to the middle. Eight of the lower river Lake Sturgeon (7 adults, 1 juvenile) went to the St. Lawrence River (half of adults), two came back. Eight (7 adults, 1 juvenile) of the lower Grasse River adults were present at Massena in the spring, then departed—two to the St. Lawrence River. The adults spent one day to three weeks at the rapids, while the juvenile frequented the area for several months. Four middle river fish and eight lower river fish were categorized as spawning at Massena Rapids in 2016. Twenty six lower river fish were foraging in the lower river, and one middle river fish was foraging in the lower river. Twenty two lower river fish overwintered in the lower, only 1 middle river fish did. Lake Sturgeon were least active in the winter, and they were most active from late-March to mid-May. In the fall they were moderately active. Of 60 tagged Lake Sturgeon, 82% overwintered in the Grasse river, and 73% of lower Grasse River overwintered in the lower river. No spawning activities were observed in the lower river (consistent with the habitat study), only in Massena Rapids. Lake Sturgeon were more common in the upstream part of the lower river than in the downstream areas of the lower river. Sixty Lake Sturgeon were aged, and the oldest was 18 years. Most of the fish were between 5 and 11 years old and may only now be reaching sexual maturity or will soon. This report includes maps that show all the locations of the tagged Lake Sturgeon, and movements.

Kleinschmidt, 2016. Final Report. Larval Lake Sturgeon drift study in the lower reach of the Grasse River, New York. Prepared for Alcoa Inc. Pittsfield, Maine.

This report summarizes the 2015 larval Lake Sturgeon drift study performed for USEPA and Alcoa in the Grasse River. The goal was to assess whether Lake Sturgeon were using the Massena Rapids as a spawning area by sampling for drifting larvae downstream of the rapids.

Methods. –They performed drift net tows (1-m net, 3 m long, 500-µm mesh, towed 100 m^3) at four transects from river kilometers 8–11 and had four stationary nets (50-cm, 150 cm long, 1,600-µm mesh) at the base of the rapids. They used Kempinger's (1988) equation for cumulative water temperature units (CTU) to determine when to sample (considering 8–10°C the beginning of pre-spawning/staging, and 10–12°C was considered the beginning of spawning). Larval Lake Sturgeon can emerge from eggs any time from 55–150 CTU (150 is peak emergence). Visual surveys for spawning and temperature monitoring was to be started at 8°C and the search for larvae began at 130 CTU OR when the first Lake Sturgeon was observed at the rapids, OR temperatures were 10°C, whichever was first. Nets were hauled every other day until CTU = 400. Nets were towed between 21:00 and 03:00 each night, four tows per transect, at a random depth between the bottom to the top of the water column. Stationary nets were set 2–5 hours, starting around 21:00.

Results. –During six weeks of sampling (April 18–May 30, 2015) 431 samples were collected but no larval Lake Sturgeon observed. Adult Lake Sturgeon were observed at May 1 at the breached weir in Massena, and on May 2 eight adults were seen at the Madrid Dam. Sixteen adults were observed at the Massena Rapids. While the flows at the rapids were sufficient for spawning, the flows were low compared to historic values, which could have been a reason for the absence of larvae. However, eggs and larvae of other fish species were captured in 83% of samples and invertebrates were found in 90% of samples. No evidence of spawning was observed at Massena Rapids, although it is possible that Lake Sturgeon do spawn at the Madrid Dam.

Kleinschmidt, 2015a. A mesohabitat assessment of Lake Sturgeon usage of the lower Grasse River, New York. Prepared for Alcoa Inc. Pittsfield, Maine. 52 pgs.
From the introduction:

> "In order to assess potential impacts of the remediation on the Lake Sturgeon population of the lower Grasse River, a habitat suitability evaluation is necessary as a first step in the process. […] The objectives of this document are to: (1) provide the findings of a review of available literature and site data for identification of possible Lake Sturgeon spawning habitat; nursery areas and refugia; and foraging and over-wintering areas within the project boundary; (2) identify any critical gaps in the knowledge base relevant to the project objectives; and (3) recommend future studies required to fill those gaps and complete this assessment."

Methods.–For the habitat assessment, no new field work was performed; existing GIS data from Alcoa was used to predict where adequate foraging/spawning/overwintering habitat would be in the lower Grasse River (from Massena to confluence with the St. Lawrence River). They used information from the Threader et al. (1998) habitat models and verified values with other literature. They modeled appropriate spawning habitat as areas with cobble/boulder substrate, water temperatures 11–17°C, depths from 0.5–6 m, water velocities 10–100 cm/s, river gradients of at least 0.6 m/km, and dissolved oxygen at least 7.5 mg/L. Nursery habitat was defined as areas with water depths less than 0.5 m, water velocities <60 cm/s, and sandy/silt substrate. Foraging habitat was defined as areas with water depths 2.5–8.5, water velocities 5–50 cm/s, and fine substrates.

Results.–No spawning habitat was found downstream of the Massena Power Canal. Massena Rapids would be suitable, but at the time of the study no spawning had been observed. While there appeared to be enough nursery habitat along the shoreline, no young-of-year or yearling

Lake Sturgeon had been found during electrofishing surveys by Alcoa and Massena Electric. They found that most of the river may provide suitable foraging habitat for juvenile and adult Lake Sturgeon. Despite the modeled availability of foraging habitat in the lower Grasse River, Normandeau Associates (2008) found that 75% of Lake Sturgeon were in the middle Grasse River, and few were permanent residents of the lower Grasse River. Lastly, they found eight potential overwintering areas (deep pools) in the lower Grasse River, most downstream of river kilometer 8. Their future recommendations included conducting movement studies to monitor use of the lower Grasse River and conducting larval drift surveys. They did not recommend further studies of nearshore areas for young Lake Sturgeon since none had been captured there previously, nor did they recommend further foraging studies. The report contains maps of all the modeled habitats.

Kleinschmidt, 2015b. Larval Lake Sturgeon drift study design for the lower reach of the Grasse River, New York. Prepared for Alcoa Inc. Pittsfield, Maine. 19 pgs.*
From the introduction:

> "The purpose of this study is to understand early life history of the Lake Sturgeon in the lower reach of the Grasse River by determining the contribution of larval Lake Sturgeon drift to downstream sturgeon recruitment in the Grasse River Remediation Project area. Attempts will be made to describe Lake Sturgeon spawning and larval drift, diel patterns, and descriptions of lateral and longitudinal drift from point of spawn. This information can then be used to evaluate potential impacts to Lake Sturgeon during the construction phase of the project."

This report simply describes the plan to perform the field work for the larval drift project, the results of which are described in Kleinschmidt (2016a). It does not appear that the methodology changed much between the plan and the work outlined in the final report (Kleinschmidt, 2016b).

Krieger, J.R., 2017. Habitat utilization and early life history characteristics of larval, young-of-year, and juvenile Lake Sturgeon (*Acipenser fulvescens*) in the Great Lakes connecting channels. Ph.D. Dissertation. University of Michigan, Ann Arbor, Michigan.
Abstract:

> "I used field surveys, geospatial modeling, and cross-system comparisons to determine if dispersal of larval Lake Sturgeon (*Acipenser fulvescens*) differed in small and large river systems and resulted in a corresponding difference in habitat use for age 0 – 2 individuals. Most species – environmental relationships have been described based on interactions observed during an animal's most dominant life history stage or extrapolated from systems where animal behavior is better understood. As a result, knowledge of habitat use during early development of a species is often poorly understood or assumed to be consistent throughout the animal's range. Using field surveys in North Channel (NC) and Middle Channel (MC) of the St. Clair River, Michigan, I assessed movement patterns of larval Lake Sturgeon and found significantly higher catch per unit effort (CPUE; No. larvae / hour) in 3 locations 0.5 – 5 km downstream from their natal reefs. Further, I found variation in larval lengths and yolk sac stages from individuals collected in single nets at each of these sites. This suggests larvae of variable ages remained in the

> river and that suitable nursery habitat existed there and was being utilized by young sturgeon. I then developed a novel habitat suitability model (HSM) to evaluate the quantity, quality, and spatial distribution of riverine nursery habitat for larval, young-of-year (YOY), and juvenile (< 500 mm) Lake Sturgeon in NC. This HSM was developed using georeferenced information on substrate, invertebrate densities, benthic current velocities, and depth. Of the 283 larval Lake Sturgeon collected, the majority were found in high quality habitat (81%) and clustered in three locations (91.2% of total catch). Nine out of 11 YOY and juveniles collected in NC were also in high quality habitat, suggesting suitable habitat also exists for young Lake Sturgeon in NC. Cross-system comparisons of the HSM developed for NC were undertaken for MC and Fighting Island Channel (FIC) of the Detroit River. Model outputs indicated a significantly higher abundance of high-quality habitat present in NC (29.1%) than MC and FIC (16.9% and 15.7%, respectively). HSM modeled output for NC indicated an abundance of suitable habitat first occurred < 0.5 km downstream from a known spawning location. Larval, YOY, and juvenile Lake Sturgeon were found in high densities at three distinct locations of high-quality habitat and appeared to utilize similar riverine habitat throughout early development. In MC, larvae also concentrated in three distinct locations of high-quality habitat. However, this habitat was less abundant and did not occur until 4.5 km downstream from MC reef. Larval collections in MC decreased as sampling progressed downstream, suggesting increased drift distance to suitable habitat resulted in increased larval mortality or alternative dispersal behavior. In FIC, high quality habitat was less common, larval Lake Sturgeon abundance was low, and larvae were not observed in high concentrations. This suggests that newly emerged larvae did not utilize available habitat in FIC, but instead drifted into the main channel of the Detroit River. My dissertation showed that dispersal of larval Lake Sturgeon in the GLCCs is strongly associated with location and abundance of suitable nursery habitat downstream from natal spawning reefs. Further, results indicated variation in habitat conditions downstream of natal reefs resulted in variable dispersal patterns of young Lake Sturgeon and should be taken into account for the planning of future restoration efforts."

New York State Department of Environmental Conservation [NYSDEC], 2018. Lake Sturgeon Recovery Plan 2018-2024. Albany, New York.
Executive summary:

> "Lake Sturgeon are long lived, large bodied, late to sexually mature, and spawn only intermittently. These characteristics make this species especially vulnerable to overfishing, and slow to recover from the severe declines they experienced in the past. In New York State, overfishing and habitat degradation led to severe declines in many of the state's Lake Sturgeon spawning populations, resulting in listing as a state threatened species in 1983. While much research has been conducted on Lake Sturgeon in the past twenty years, we still lack sufficient knowledge of specific spawning locations for some populations, as well as population abundances and age structure for many of the populations. To change the New York State listed status of this species from Threatened to Special Concern, or to remove it from the list altogether, there needs to be sufficient self-sustaining populations in the state to warrant that change. Defining these populations and an accompanying target number for recovery proved challenging since Lake

> Sturgeon occupy wide ranging and variable habitats across New York. In many cases, smaller spawning aggregations may be part of a larger metapopulation. To accommodate these variances, we defined Management Units across New York as a descriptor of these metapopulations. Self-sustaining populations of Lake Sturgeon are defined in this plan as having an estimate of at least 750 spawning adults across all spawning aggregations within a Management Unit and detection of at least three years of wild reproduction in a five-year period. A stocking program by New York State Department of Environmental Conservation (NYSDEC) and the United States Fish and Wildlife Service (USFWS) has been in place since 1993 to achieve these goals. Lake Sturgeon have been re-established across the state and current stocking is seeking to enhance the genetic diversity of the stocked populations. Naturally recovering populations are also being monitored in several Great Lakes locations. Spawning habitat enhancement is taking place at several locations in the St. Lawrence River, and the Seneca River. NYSDEC, USFWS, US Geological Survey (USGS), Cornell University, Saint Regis Mohawk Tribe (SRMT), many local governments, non-governmental organizations, and utilities are working toward these goals. Contributions from all will be necessary to accomplish recovery of this species."

New York State Department of State [NYSDOS], 1994. Coastal fish and wildlife habitat rating form for Grass River, St. Lawrence County. Designated May 15, 1994 in the towns of Massena, Louisville, Waddington, and Madrid. Albany, New York.
This document is a rating form that designates the Grasse River as Significant Coastal Fish and Wildlife habitat (SCFWH) by the New York State Department of Environmental Conservation (then officially designated as such by the Department of State). Habitats are rated/designated as part of the mandate of the Waterfront Revitalization and Coastal Resources Act (WRCR) of 1981 and are afforded special protections (Ozard, 1984). The Grasse River ("Grass" in the language of the rating form) was designated as SCFWH on 15 May 1994 and includes area in six quadrangles (Raquette River, NY; Massena, NY; Louisville, NY; Chase Mills, NY; Waddington, NY; Morley, NY) and four towns (Massena, Louisville, Waddington, Madrid) in St. Lawrence County. There are several rating criteria: ecosystem rarity, species vulnerability, human use, population level, and replaceability. A brief overview of the rating system (from Ozard, 1984) and calculation of the habitat rating(s):

1. Ecosystem rarity (ER, 0–100, where 0 = not rare, and 100 = unique):
   "…the "uniqueness" of the plant and animal community and the physical, structural and chemical features which support this community. Each habitat which is to be evaluated must be large enough and healthy enough to sustain its own fish and wildlife community on a long term or repeating basis. […] The levels of ER are: unique, rare in the United States, rare in New York, rare in a major ecological region of New York, rare in an ecological subzone of New York, rare in the county or not rare."
2. Species Vulnerability (SV, 0–36, where 0 = not vulnerable and 36 = endangered):
   "…reflects the degree of vulnerability of a species throughout its range in New York State. Vulnerable species shall be defined as those species listed as Endangered, Threatened, or of Special Concern."
3. Human Use (HU; 0–49, where 0 = no significant human use and 49 = world use):
   "…refers to significant (i.e. demonstrable) commercial, recreational or educational wildlife related human uses. The uses may be either consumptive or non-consumptive, and may be on the area itself, or if off the area, directly dependent upon the area. […]

The uses are considered in terms of significant commercial, recreational or educational use in: the world, the United States, a major region of the United States, New York, a major region of New York, a county or no significant human use values."

4. Population Level (PL, 0-49, where 0 = no unusual concentration and 49 = most unusual concentration in the world):

   "…refers to the concentration of a species on an area during its normal period of occurrence. For instance, an ecosystem may be important to waterfowl for only one month each spring, but loss of that habitat may have a significant long term effect upon the waterfowl population. In this case, the area would receive a PL score for the concentration during which the ecosystems use by waterfowl is important. The PL concentration must be a repeating long term phenomenon. […] The values for the PL concentration are unusual in: the World, United States, a major ecological region of the United States 6, New York, a major ecological region of New York, a county or there is not an unusual concentration."

5. Replaceability (R; 0.4-1.2, where 0.4 = can be replaced in 2 years, 1.2 = irreplaceable):

   "…an equivalent replacement for the same fish and wildlife and uses of that fish and wildlife. Replacement may be either on site or off site; however, if R is off site, it must meet the needs of the same human users and be comprised of the same fish or wildlife population. […] An ecosystem may be: irreplaceable, difficult to replace or its replaceability may be uncertain, reasonably likely to be replaced, easily replaced by well understood techniques, or replaced naturally by independent processes within two years."

6. Equation: SIGNIFICANCE = HI * R; where HI = ER + SV + HU + PL. Habitats with significance values over 15.5 are recommended to NYSDOS for designation as SCFWH (in general, more rules apply).

Overall, the significance value for the Grasse River was a 76, with a ER = 25 ("One of only three major tributaries in the St. Lawrence Plains ecological region; in relatively undisturbed condition"), SV = 25 ("Lake Sturgeon (T) present and presumed to successfully spawn based on age of individuals observed"), HU = 4 ("Recreational fishery of county level significance"), PL = 9 ("Only documented population of muskellunge inhabiting a small river system in the St. Lawrence Plain ecosystem. Possibly a rare refugium for St. Lawrence River muskellunge following the construction of the St. Lawrence Power project"), R = 1.2 ("Irreplaceable").

The remainder of the document outlines activities that should not be allowed and must be considered when an entity wants to alter the habitat in some way:

> "Any activity that would substantially degrade water quality, increase turbidity or sedimentation, reduce water levels, alter flows, or increase water level fluctuations in the Grass River could adversely affect the biological productivity of this unique St. Lawrence River tributary. […] Elimination of associated wetland habitats, or substantial human encroachment into the area, as a result of dredging, filling, construction of roads, or motorboat access development, could severely reduce its value to fish and wildlife. Because of the year-round fish and wildlife use of the area, dredging activities at any time of year may affect certain species, and should not be permitted outside of existing channel areas at the confluence of the Grass and St. Lawrence Rivers. Increased public access to the Grass River could lead to habitat impairment during fish spawning and nursery periods (March - July for most resident species), and wildlife breeding seasons (April - July for most species). Also of concern in this major tributary are the potential effects of upstream activities, including flow alterations, stream bed disturbances, and

> discharges of industrial effluents. Development or operation of hydroelectric facilities should optimize aquatic habitat values by reducing flood flows and maintaining minimum flows. Barriers to fish migration in the Grass River, whether physical or chemical, would have significant effects on fish populations in the area. [...] Existing areas of natural vegetation bordering Grass River should be maintained for their value as cover for wildlife, perching sites, and buffer zones from human disturbances."

Lastly, the document suggests that additional studies should be performed to determine appropriate management strategies for the Lake Sturgeon and Muskellunge (*Esox masquinongy*) in the river.

Normandeau Associates, Inc. [NAI], 2009. Lake Sturgeon (*Acipenser fulvescens*) abundance, seasonal movement, and spawning behavior in the Grasse River, St. Lawrence County, New York. Prepared for Town of Massena Electric Department, in: Volume 1. Massena Grasse River Hydroelectric Project FERC Project. Updated Study, Massena, New York. 133 pgs.

Goals and objective from section 1.1:

> "Studies initiated in 2006 (Normandeau 2006) and 2007 (this report) relating to sturgeon abundance, spawning and seasonal movements were continued during 2008 to provide a more complete understanding of Lake Sturgeon behavior in the Grasse River. The movements of ten juvenile and four adult Lake Sturgeon which were radio-tagged during 2007 were monitored during 2008. Potential spawning areas were studied using egg traps in the river stretch between the breached weir and the Massena Power Canal, as well as the known Lake Sturgeon spawning area below the Madrid Dam, and additional effort was expended to tag up to 9 more adult Lake Sturgeon. This study seeks to understand the population size and river use by Lake Sturgeon, the timing of spawning and related movements, and the general movement of sturgeon within the portion of the Grasse River potentially affected by the proposed dam and reservoir. Field studies during 2007 and 2008 attempted to address the following: What is the abundance of Lake Sturgeon in the Grasse River from the confluence of the Grasse and the St. Lawrence River upstream to the next impassable barrier at Madrid? Do Lake Sturgeon utilize the river reach from the Massena Power Canal upstream to the breached weir for spawning? In the proposed Project area, how do adult Lake Sturgeon of spawning size move about the proposed Project area, when do they move about that area, and how do they use the area (e.g., staging or seasonal habitats)? What is the extent of movements of juvenile Lake Sturgeon within the proposed Project area?"

Methods. – They performed gill net surveys for five weeks (April 1– May 4, 2007) at eight sites and kept nets away from Massena and Madrid dams to prevent catching spawning Lake Sturgeon. They placed two nets per station for two days per week that were deployed for four-hour sets. The gill nets had mesh sizes of 1.27, 15.2, and 17.8 cm. Later they added five-panel gill nets to each station (3.8, 5.0, 7.2, 10.2 and 12.8-cm meshes). All Lake Sturgeon captured in gill nets were pit tagged to check for recaptures. They also performed an egg trap study from April 29 to May 10, 2007. The egg traps were cement blocks (10.2 x 20.3 x 40.6 cm) wrapped in hog's hair synthetic filter media. They placed three lines (three blocks per line, 2.3 m apart) at four potential spawning areas between the breached weir and the Massena Power Canal, for a total of 50 traps. Traps were placed in areas with water velocities at least 0.6 m/s and fished overnight and checked daily for 12 days. Another egg trap study occurred in 2008 (April 20–May 2), this time with four blocks/line at thirteen locations between the breached weir and Massena Power Canal. Traps were added to an area where a dam was proposed and near Madrid (40 traps). Traps were checked every 48 hours. Lastly, they performed stationary and manual tracking of Lake Sturgeon with radio telemetry: 10 adults and 7 juveniles were tagged and tracked from tagging (July 2007 for juveniles, fall 2007 for adults) to September 3, 2008. Two stationary receivers were placed at river kilometer (rkm) 1.8 (near confluence of St. Lawrence River) and at rkm 7.8 (near the breached weir at Massena). Manual tracking occurred every day during the 2007 gill netting survey and occurred twice a month from the spring to fall 2007, then monthly from December 2007 to March 2008. In April 2008, manual tracking occurred every day during the potential spawning season.

Results. – They captured 50 Lake Sturgeon from April 1 to May 4, 2007—four were recaptures, the rest were tagged. Most of the Lake Sturgeon were captured in the Massena pool area, and the middle river accounted for 75% of catch. The total number of Lake Sturgeon captured in the previous season and this survey was 192. Using the Schumacher-Eschmeyer estimator, the population of Lake Sturgeon was estimated to be 592 over 480 mm (lower 95% confidence interval: 480, high 95% interval: 760), and using the Schnabel estimator there were 585 fish over 480 mm (lower 95% interval: 441, higher 95% interval: 872). No Lake Sturgeon eggs were found in 2007 egg traps (although a total of 606 eggs of other species were found), and in 2008 there was a single Lake Sturgeon egg found in the Madrid Dam tailwater on April 25 of 1,165 total eggs. The Lake Sturgeon egg corresponded with a tagged female at the Madrid Dam tailwater during the spawning season. There were 3,200 other fish eggs found from the weir to the Massena Power Canal in 2008, none of which were Lake Sturgeon. Ages of captured Lake Sturgeon were estimated to be 0–20 years (aged using pectoral spines), with a mean of 8.1 years and dominated by those 5–9 years old. The estimated mortality rate from catch curves was 21.2%, which seems to be in line with those of other Lake Sturgeon. The seasonal movements of adult Lake Sturgeon varied by fish, some exhibited large-scale movements while others stayed within a reach. Two individuals used the St. Lawrence River for part of the year. Most juveniles (90%) stayed within the reach in which they were captured, but some moved > 8 km. Unfortunately, none of the maps of Lake Sturgeon movements are visible in the PDF of the report.

Roseman, E.F., J. Boase, G.K., Craig, J., Soper, K., 2011. Adaption of egg and larvae sampling techniques for Lake Sturgeon and broadcast spawning fish in a deep river. Journal of Applied Ichthyology 27, 89–92.
Abstract:

> "In this report we describe how we adapted two techniques for sampling Lake Sturgeon (*Acipenser fulvescens*) and other fish early life history stages to meet our research needs in the Detroit River, a deep, flowing Great Lakes connecting channel. First, we developed a buoy-less method for sampling fish eggs and spawning activity using egg mats deployed on the river bottom. The buoy-less method allowed us to fish gear in areas frequented by boaters and recreational anglers, thus eliminating surface obstructions that interfered with recreational and boating activities. The buoy-less method also reduced gear loss due to drift when masses of floating aquatic vegetation would accumulate on

> buoys and lines, increasing the drag on the gear and pulling it downstream. Second, we adapted a D-frame drift net system formerly employed in shallow streams to assess larval Lake Sturgeon dispersal for use in the deeper (>8 m) Detroit River using an anchor and buoy system."

Threader, R.W., Pope, R.J., Schaap, P.R.H., 1998. Development of a habitat suitability index model for Lake Sturgeon. Ontario Hydro No. H-07015.01-0012. Toronto, Ontario.
Synopsis from Dick and Choudhury (1992):

> "The purpose of developing a Habitat Suitability Index model for Lake Sturgeon was to predict the effects of future construction of, modifications to, or operation of hydroelectric generating facilities in Ontario. Age, growth, food, reproduction and specific habitat requirements were discussed. The model was designed for large, low-gradient rivers of north-central Ontario but is applicable throughout the Lake Sturgeon's native range. Spawning, incubation and summer foraging habitats for riverine Lake Sturgeon populations are evaluated. Some information on summer foraging of lacustrine populations was also integrated. Two model components representing two life requisites of Lake Sturgeon were included. These were food and reproduction. For the food component, four habitat variables were selected. These included adult foraging substrate types, juvenile foraging substrate types, water depth and velocity. The four indicators of habitat suitability chosen for the reproduction component were water temperature, water velocity, substrate type and water depth. Suitability Index graphs were constructed for the eight previously mentioned variables by converting habitat information from published documents and personal communications into habitat suitability graphs ranging from 0 (unsuitable habitat) to 1 (optimum habitat). Rationale, assumptions and information sources for each variable were discussed, and the computer model and output were included in the appendices."

Vaccaro, L., Bennion, D., Boase, J., Bohling, M., Chiotti, J., Craig, J., Drouin, R., Fischer, J., Kennedy, G., Manny, B., Read, J., Thomas, M., Roseman, E., 2016. Science in Action: Lessons learned from fish spawning habitat restoration in the St. Clair and Detroit rivers. No. MICHU-16-501. University of Michigan, Ann Arbor, Michigan. 44 pgs.
From the introduction:

> "This publication summarizes lessons learned from a series of fish spawning habitat restoration projects completed between 2004 and 2015 in the St. Clair and Detroit rivers. This work resulted from a long-term collaboration among federal, state and private groups interested in studying and restoring the St. Clair-Detroit River System. This publication was developed to capture and share the ideas and experiences of the habitat restoration partners. Content was adapted from a number of journal articles and reports."

This document outlines the case for fish habitat restoration in the Saint Clair-Detroit River System (SCDRS), the adaptive management framework used, the team formed, planning the projects, avoiding issues with navigation and sedimentation, project permitting and construction, results and outcomes, and some selected case studies. The SCDRS restoration was needed to compensate for loss of fish spawning habitat through dredging and channelization of the systems in the 1800s and early-1900s. Lake Sturgeon and other lithophilic fish species require rocky habitat for spawning and egg incubation, and the goal of the project was to create artificial spawning reefs.

The team operates under an adaptive management framework, which includes these steps: 1) assess the problem, 2) build consensus, 3) develop a restoration plan, 4) implement restoration actions, 5) monitor and evaluate outcomes, and 6) make adjustments based on lessons learned. The team worked well for the following reasons: the team came together due to personal relationship and regional collaborations but stayed together without a formal agreement for 10 years, coordinating the team and money required time and skills that had to be budgeted for, there were quarterly meetings and regular email updates, outreach was incorporated into all parts of the project, shared decision making was used to makes sure everyone was responsible for planning.

To plan the reef projects, possible sites were identified using GIS models and field work, and three basic criteria were used: physical attributes of the river (deep water to limit algae growth, fast flows to prevent sedimentation, no sediment contamination/pollution, within US border, smooth flat bottom with no existing habitat), ecological attributes (fast flows for egg oxygenation, connected to potential nursery areas, areas where Lake Sturgeon travel or spawn), and human use of the river (outside of navigation channels, shoreline property owners give permission, no interference with marine navigation).

Some of the key lessons learned in project permitting/construction/monitoring: pilot projects helped show utility of work and garnered future funding, reef designs were improved over time by finding ways to reduce sedimentation and prevent sea lamprey spawning, and stakeholder groups should be consulted early in the permitting process.

To prevent issues with sedimentation, dredging records should be assessed and the river current/shape should be studied to see where erosion and deposition will occur. Sedimentation is assessed on the reefs with side-scan sonar, divers, and underwater cameras, and water velocity was measured with acoustic Doppler current profilers and models were made from these data. A pilot reef was first placed in 2004 near Belle Isle in the Detroit River. As of the time of the report, six total reefs were built (3 in the Saint Clair, 3 in the Detroit River). Pre- and post-reef building assessments of fish found a variety of fish species spawning (18 native fish) on or visiting the reefs for other reasons (15 species).

Appendix 2. Example Collaboration: St. Clair-Detroit River System Initiative

This section describes the organizational structure and function of the Saint Clair-Detroit River System Initiative (SCDRSI). The SCDRSI is a bi-national collaborative partnership with more than 30 organizations, including U.S. and Canadian natural resource-related agencies, First Nations, units of local government, industry and university partners, non-profits, and interested citizens. The SCDRSI partners share a common vision: the restoration of portions of southern Lake Huron, the Saint Clair River (hereafter St. Clair River), Lake Saint Clair (hereafter Lake St. Clair), the Detroit River, and western Lake Erie to a thriving ecosystem with science-based management and broad social support that provides environmental services for the region and the Great Lakes basin (http://www.scdrs.org). To achieve this vision, the SCDRSI has championed several large-scale habitat restoration projects, research, monitoring, and outreach efforts for over a decade that have resulted in delisting of multiple Beneficial Use Impairments (BUIs) and improved fisheries and wildlife habitat and population status in the St. Clair and Detroit rivers' Areas of Concern (AOCs). What follows is a description of the evolution of the SDCRSI and some of the conceptual practices that contributed to partnership development, consensus building, and restoration success.

The collaboration that would later become the SCDRSI began as a group of researchers and managers wanting to enhance spawning habitat in the Detroit River in 2004. This group worked together to bring the best ideas and latest results to get these projects completed and monitored effectively and efficiently using an adaptive management approach (Figure A2.1; Manny et al., 2015; Vaccaro et al., 2016). The monitoring and research demands were delegated amongst the agencies and continuous communication occurred year-round. This allowed for questions to be addressed and any issues solved in real time. The group met annually to go over findings and updates, as well as plans for upcoming years. While the communication lines were open between professionals directly involved with the work, information was communicated up organizational chains-of-command and to the public. This small group worked together well and began to increase in size as their own personnel numbers increased with the increased need for research and monitoring efforts, but also because other agencies and organizations outside of fisheries habitat restoration were aware of the effectiveness of this organized collaboration and began to take part in the annual meetings and field efforts. In 2013, the SCDRSI was officially organized and expanded the focus from fisheries habitat to include all environmental and related societal research and monitoring needs of the system.

One very important aspect that was different when the SCDRSI officially formed compared to the previous collaboration was the establishment of a governance structure (partnership agreement; Figure A2.2), strategic vision for the St. Clair-Detroit River System (Table A2.1), and priority objectives defined by the membership (Table A2.2). It was discovered that the previous collaboration was loosely following the collective impact framework put forth by Kania and Kramer (2013), so this formal collaboration decided to fully use this framework when setting up the formal aspects of the collaborations (Table A2.3). This framework has components that are flexible and easy to understand and has been shown to be effective in other settings around the country for diverse collaborations where the collaborators are open, honest, transparent, and supportive. The transition to this framework ensured the non-fisheries habitat interests were fairly included and considered.

We will now give a brief explanation of the components of the collective impact framework and how it was addressed within the SCDRSI. It is important to note that in order for this framework to be effective all parties agreed that this was to be an inclusive collaboration. Some guidelines agreed upon initially were that 1) members would be polite, generous, and easy to work with, 2) have and attend open meetings, 3) be transparent, 4) engage in active recruitment of new partners, new experts, and new issues, 5) co-author publications and disseminate scientific findings; participate in grant writing collaborations, 6) make use of local contributions of matching funds and in-kind services, 7) create opportunities to communicate, 8) follow 'one person-one vote' during meetings and 'one agency-one vote' on the steering committee, and 9) conduct team-building activities (working groups, exercises, field trips, provide food/meals).

The first component of the collective impact framework is the establishment of a common agenda (Figure A2.3). This step included identifying problems, establishing goals (there could be many), and identifying the shared strategic vision (one overall vision, few 'sub-visions'; https://scdrs.org/wp-content/uploads/2015/09/SCDRS-Strategic-Vision_FINAL_6Feb2014-6.13.14.pdf). This was one of the more difficult and abstract aspects of the framework to complete because it needed to be specific, yet broad enough to apply to our large geographic area. We invested resources to get assistance with this through hiring a consultant to help develop the strategic plans and vision through many meetings and consultations with our members. The consultant was able to focus on our collaboration, develop conceptual models of all components, and compare how our framework was developing to other groups and ecosystems, ensure smaller goals and priorities were linked to the larger perspective, and make geo-referenced data layers for our use now and in the future.

The second component was to establish a shared measurement system. Through meetings, calls, and open communications, members agreed on what to measure to gauge progress, standardized collection methods, standardized reporting, and what values would constitute success (https://scdrs.org/wp-content/uploads/2015/09/IndicatorDescriptionsForGoogleForm-9.23.15.pdf). Concurrent with these efforts, a viability analysis was completed for the SCDRS for biotic and abiotic conditions of interest within different sections of the system (DeBruyne et al., 2019). The viability analysis identified the current conditions of the selected metrics and provided a condition status where possible. A report card highlighting the values and conditions of metrics associated with the priority objectives is provided at the annual SCDRSI meetings (Figure A2.4; https://scdrs.org/resources/). The report card is completed in consultation with the topic experts and those completing the monitoring and research in the system. Additional details that are provided with the report card include the metric trajectory (increasing, decreasing, stable), progress toward the established goals and objectives, and any relevant changes in the system state.

The third component for successful collective impact is to have mutually reinforcing activities. The SCDRSI developed and organized multiple interdisciplinary teams to address both specific topic interests/objectives and broader, encompassing committees including the communication committee and the science and monitoring committee. These committees have a broad list of possible activities and responsibilities including planning collaborative work; developing and facilitating complementary efforts that are not duplicative nor competitive; suggest ways to share workloads and resources; suggest mixed-agency field crews and think-groups where needed; share data and samples; and conduct or suggest value-added surveys to make use of boat/crew time. All the above possibilities and activities of our committees rely on informative and responsive communication between partners.

The fourth component, and perhaps one of the most crucial, is to have open and continuous communication between partners in collective impact. For the SCDRS this is done through regularly scheduled meetings for the membership-at-large and the steering committee, conference calls, group emails, and website updates. Communication can be initiated by members or by the communications committee. The communications committee is a standing committee within the governance structure of the SCDRSI and through its defined duties keeps the initiative moving forward towards the goals and objectives.

The final component of a successful collective impact collaboration is the designation of a backbone support organization. The U.S. Geological Survey Great Lakes Science Center served as the first backbone organization; however, the duties of backbone organization now move to different steering committee organizations to reduce the burden. SCDRSI started around 2004 as the 'Huron-Erie Corridor Initiative' with a few agency biologists. Over the course of the next decade, it grew in terms of agency/stakeholder participation and in scope of issues discussed and considered. Today the SCDRSI is comprises more than 40 member, partner, and supporting organizations (https://scdrs.org/partners/). The SCDRSI developed a formal organizational structure to share leadership responsibilities (e.g., steering committee roles) and participation is on a scheduled rotating basis.

SCDRSI Success Stories

Artificial Spawning Reefs.–The SCDRS has undergone dramatic anthropogenic changes over the past 150 years, including the creation of navigational channels which resulted in the removal of valuable spawning habitat for lithophilic spawning fishes and collapse of local fisheries. To remediate this issue, seven reefs (~20 acres total) have been constructed in the SCDRS from 2004–2018. A variety of fish species have been observed to use the reefs for spawning, including immediate use by Lake Sturgeon, a target species for restoration (Roseman et al., 2011). Eggs from Lake Whitefish (*Coregonus clupeaformis*), Walleye (*Sander vitreus*), a variety of suckers (Family Catostomidae), and other species have also been found on constructed reefs (Prichard et al., 2017; Vaccaro et al., 2016). The SCDRSI planned the construction of the reefs (taking into consideration lessons learned from previous projects), coordinated pre- and post-construction monitoring of reefs to determine their effects on fish populations at all life stages from eggs to adult fish, and monitors the physical condition of the reefs over time. These projects helped lead to the 2017 removal of the 'Loss of Fish and Wildlife Habitat' BUI in the St. Clair River.

Islands Protection and Restoration.—One goal of the SCDRSI is to increase riparian connectivity and to restore softened shorelines. A lake on Belle Isle was reconnected to the Detroit River and the Blue Heron Lagoon to provide valuable habitat for a variety of aquatic and non-aquatic species and to provide enhanced recreational opportunities. Restoration of ~2000 m of historic shoals and coastal wetlands is taking place along Stony and Celeron islands in the Detroit River, which will provide protection from erosion and provide habitat for birds (shoals) and fish (wetlands). Additional restoration of upland habitats provided refuge for snakes, turtles, and other taxa.

Softening Shorelines.—To accommodate shipping and development, large swaths of the SCDRS shorelines have been armored with concrete or steel, including approximately 97% of the US Detroit River shoreline. One of the goals of the SCDRSI is to 'increase riparian complexity/connectivity through increased softened shorelines and native riparian vegetation', and many organizations and municipalities along the SCDRS are implementing shoreline softening projects. Efforts to create softened shorelines allowed for assessment of best practices and study of effects to fish communities. These projects helped lead to the 2017 removal of the 'Loss of Fish and Wildlife Habitat' BUI in the St. Clair River.

Continued Coordinated Science and Monitoring.—The SCDRSI coordinates research and monitoring activities from many organizations, including projects such as: monitoring fish migration via acoustic telemetry, status assessments of fish, bird, plankton, benthic, and herpetological communities, aquatic invasive species and lamprey monitoring, water chemistry monitoring for contaminants of concern and nutrients, monitoring river flow, identifying sources of nutrients, and measuring societal satisfaction. These projects aid in the removal of additional BUIs in the SCDRS.

Considerations for creating an effective habitat restoration partnership organization, based on the SCDRSI model:

a. Follow principles of Collective Impact (Table A2.3; Kania and Kramer, 2013), and the Manny et al. adaptive management approach (Figure A2.1; Manny et al., 2015), form a partnership agreement and decide upon a Common Agenda and Strategic Vision.
b. Earn public support: create and hold interest, trust, transparency, outreach component, and communicate at the public stakeholder level. For example, Michigan Sea Grant outreach efforts include high school education programs, 'show and tells', and work with stakeholder organizations such as the Friends of Detroit River and the Riverkeeper. Participate in and sponsor events, go to their meetings, participate in agency outreach efforts, engage the news media, garner local champions, and feature a charismatic example species. Give credit when credit is due.
c. Earn scientific relevance and credibility: actively seek input from experts, communicate your global significance, show up at meetings, actively and effectively communicate at multiple levels, publish, and share data and samples. Include local universities through graduate research opportunities.
d. Employ an ecosystem perspective: include landscape perspective, understand metapopulation dynamics and connectivity, model populations with stocks portfolio concept, and conduct a viability analysis. Consider management of adjoining systems and how this system can contribute to achieving their goals, e.g., the Great Lakes Fishery Commission's Fish Community Goals and Objectives for Lake Erie (Ryan et al., 2003).
e. Embrace the socio-economic aspects of the system: identify valued ecosystem services, consider how restoration and management will improve ecosystem services. Measure the economic effects of these services through creel surveys or other means.
f. 'Think Big': dealing with a big ecosystem at landscape and watershed scales, big populations, big foodwebs, big partnerships, big money. Think: "Local impacts - global significance."
g. Think long-term: What are your 5-year or 10-year goals? Develop management plans, science and monitoring plans, commit to long-term programs, and create budgets to follow that timeframe.
h. Experiment and monitor: ask the right questions, be curious, use adaptive management principles, learn from experimenting, measure the right parameters to gauge progress, and apply what was learned.

Summary

- To achieve its goals, the St. Clair-Detroit River Initiative:
    - Implemented the collective impact and adaptive management frameworks
    - Developed an interdisciplinary team, including stakeholders, transparent activities, and active communication
    - Adapted a broad ecosystem perspective that considered habitat connectivity, metapopulation dynamics, and the stock portfolio concepts
    - Considered multiple scales of ecosystem, landscape, watershed, and socio-economic situations
    - Routinely communicates to assess progress and identify/address new emerging issues

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Tables

Table A2.1. Strategic Vision and Common Agenda of the Saint Clair-Detroit River System Initiative, 2015–2030.

Strategic Vision Statement	The Saint Clair-Detroit River System is a thriving ecosystem managed with science-based principles and broad social support, providing desired environmental services for the region and the Great Lakes basin.
Common Agenda	Restoration, protection and sustainability of the System will be accomplished through adaptive and coordinated decisions, focused science, timely assessment and evaluation, and communication among partners, to provide sustained improvements to: physical, biological and chemical features of habitats; production and biodiversity of indigenous species; prevention or mitigation of negative impacts from aquatic invasive species; and societal satisfaction in the system.

Table A2.2. Saint Clair-Detroit River System (SCDRS) ten-year priority objectives.

1	Complete habitat improvement projects to remove loss of fish and wildlife habitat Beneficial Use Impairments (BUIs)
2	Reduce loading from regulated and unregulated sources of total phosphorus (TP) and dissolved reactive phosphorus (DRP)
3	Identify contaminants of concern, determine sources, and develop load reduction strategies
4	Increase riparian complexity/connectivity through increased softened shorelines and native riparian vegetation
5	Increase continuous area of functional wetlands and their connectivity to the SCDRS.
6	Increase river spawning habitat
7	Identify and protect critical habitat areas for rare species, including river mouth habitats and connectivity within tributaries.
8	Develop surveillance monitoring for Aquatic Invasive Species (AIS) based on habitat requirements and availability
9	Implement preventive strategies through information and education programs and management of potential sources and pathways (AIS)

Table A2.3. The five conditions of collective impact from Kania and Kramer (2013).

1. Common Agenda	All participants have a shared vision for change including a common understanding of the problem and a joint approach to solving it through agreed upon actions.
2. Shared Measurement	Collecting data and measuring results consistently across all participants ensures efforts remain aligned and participants hold each other accountable.
3. Mutually Reinforcing Activities	Participant activities must be differentiated while still being coordinated through a mutually reinforcing plan of action.
4. Continuous Communication	Consistent and open communication is needed across the many players to build trust, assure mutual objectives, and create common motivation.
5. Backbone Support	Creating and managing collective impact requires a separate organization(s) with staff and specific set of skills to serve as the backbone for the entire initiative and coordinate participating organizations and agencies.

Figures

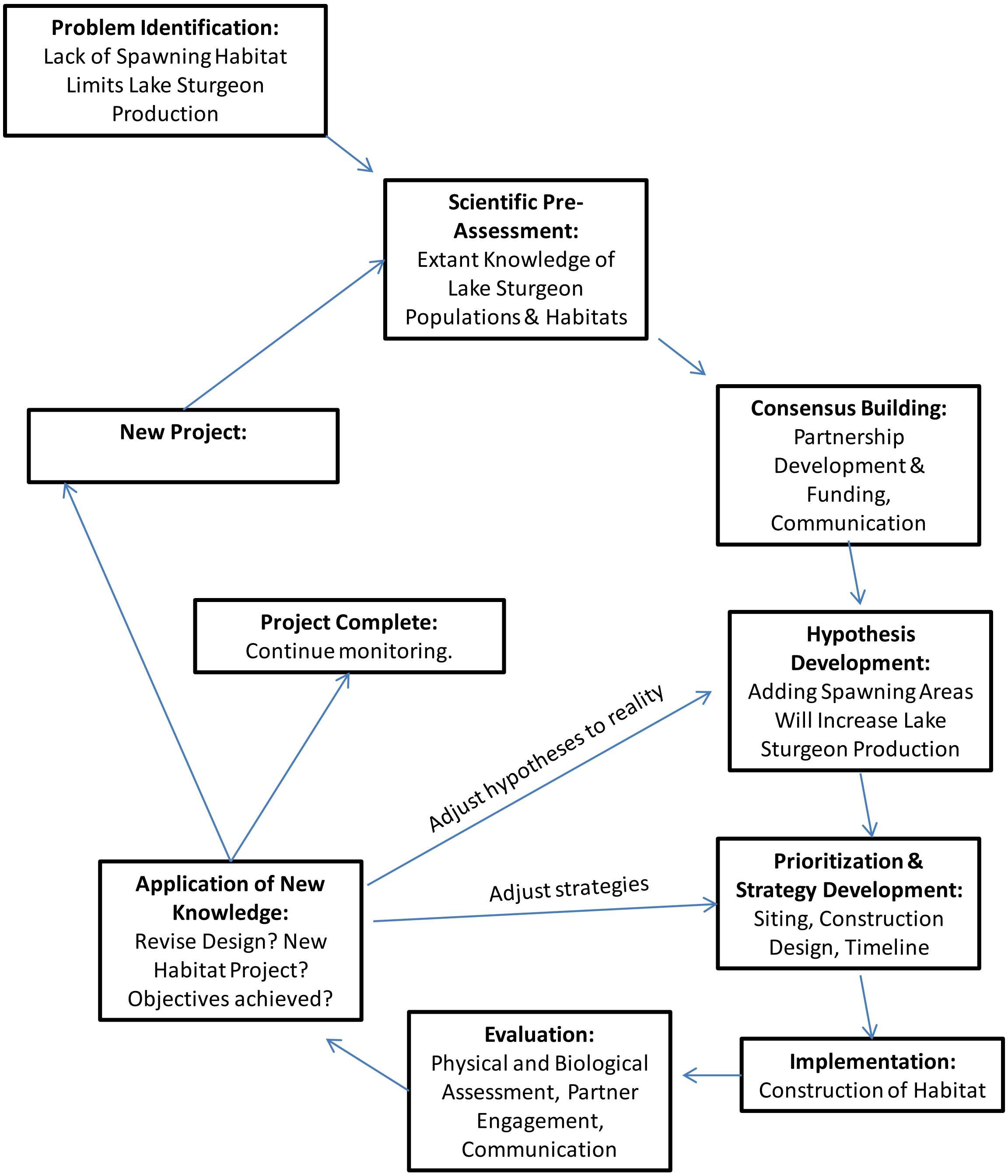

Figure A2.1. Adaptive management approach to fish spawning restoration employed by the Saint Clair-Detroit River System Initiative (Manny et al., 2015).

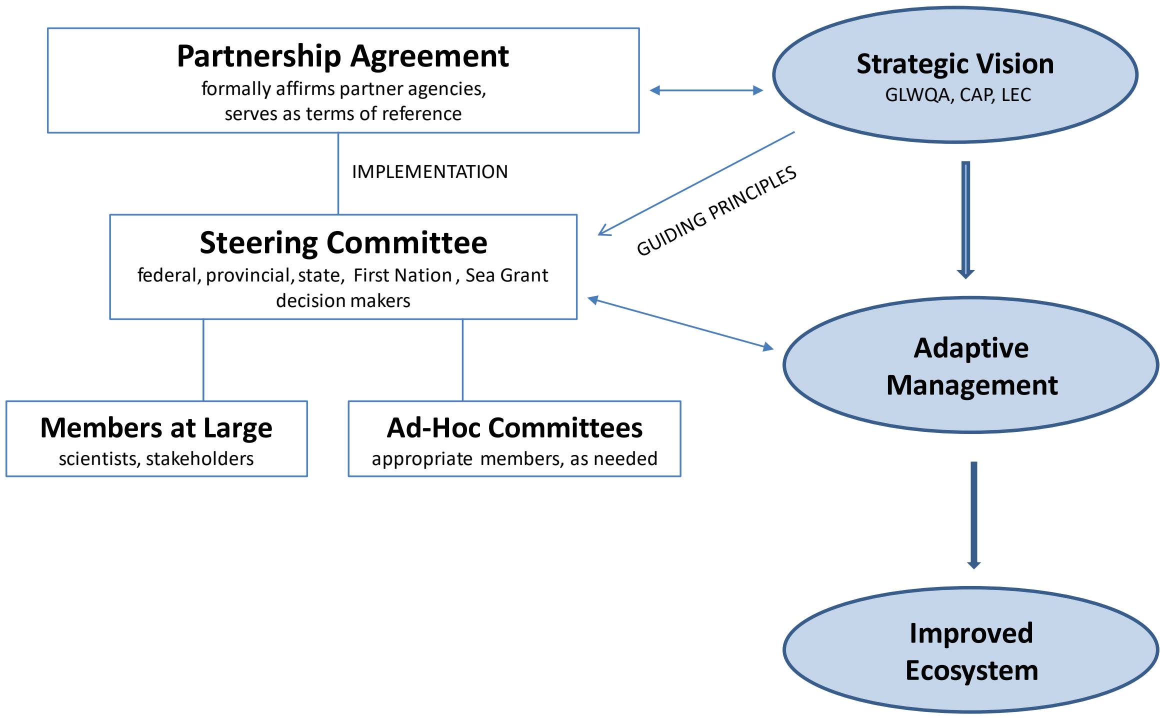

Figure A2.2. Saint Clair-Detroit River System Initiative governance structure. GLWQA = Great Lakes Water Quality Agreement; CAP = Conservation Action Plans; LEC = Lake Erie Committee.

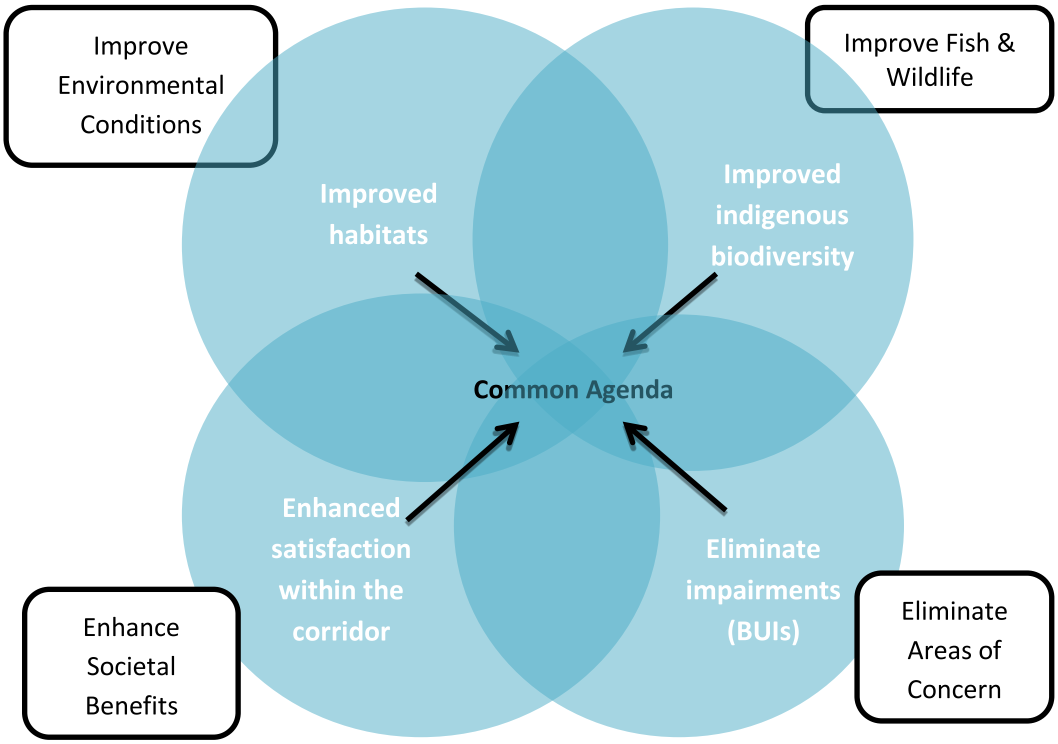

Figure A2.3. Saint Clair-Detroit River System Initiative focus areas.

St. Clair – Detroit River System Initiative Report Card 2017

Indicator Status for Priority Objectives updated 2/23/2018

Status:	**Very Good**	**Good**	**Fair**	**Poor**	**Undetermined**
Trend:	**Improving**		**Unchanging**	**Deteriorating**	**Undetermined**

Habitat Related Indicators

Priority Objective	Indicator	Reporting Frame	Status
Complete habitat improvement projects to remove loss of fish and wildlife habitat Beneficial Use Impairment (BUI)	Number of projects left to complete leading to the removal of this BUI in the Detroit River	Annually	9; Unchanging
	Number of projects left to complete leading to the removal of this BUI in the St. Clair River	Annually	Complete
	Canadian response indicators	Annually	Research and monitoring need
Increase riparian complexity/connectivity through increased softened shorelines and native riparian vegetation	Artificial shoreline index: increase percentage of softened shoreline by removing artificial structures (e.g., sea walls and rip rap)	Opportunistically	Unchanging
	Amphibian Index of Biotic Integrity (AmphIBI) for Wetlands (Ohio EPA)	Opportunistically	Research and monitoring need
Increase the continuous area of ecologically functional wetlands and their connectivity to the SCDRS	Percent of accessible tributary habitat	Opportunistically	Unchanging
	Wetland area	Opportunistically	Unchanging
	Marsh bird IBI	Opportunistically	Unchanging
	Invertebrate IBI	Opportunistically	Research and monitoring need
	Amphibian Index of Biotic Integrity (AmphIBI) for Wetlands (Ohio EPA)	Opportunistically	Research and monitoring need
	Wetland fish index (WFI) of wetland quality	Opportunistically	Unchanging
Increase functional river spawning habitat for native lithophilic species in main channel and tributaries	Area of main channel (St. Clair and Detroit rivers) habitat suitable for lithophilic spawners (hectares)	Annually	Undetermined
	Percent of accessible tributary habitat	Opportunistically	Unchanging
	Mean 5-year annual peak density of pelagic larval whitefish and walleye (#/1000 m^3)	Annually	Unchanging
	Mean 5-year catch per unit effort of adult walleye, shorthead redhorse, lake whitefish, and burbot	Annually	Undetermined
	Mean 5-year catch per unit effort of juvenile lake sturgeon (< 1000 mm)	Annually	Undetermined
Identify and protect critical habitat areas for rare native species in main channel and tributaries	Mean 5-year catch per unit effort of juvenile lake sturgeon (< 1000 mm)		Undetermined
	Additional indicators		Research and monitoring need

Many of the status ratings were taken from the SCDRS Viability Analysis and Lake Erie Biodiversity Conservation Strategy (Pearsall et al. 2012)

Figure A2.4. An example from the 2017 Saint Clair-Detroit River System Initiative Report Card. https://scdrs.org/wp-content/uploads/2018/09/SCDRS-Report-Card-2.23.18-FINAL.pdf