Avian Status Report

Avian Habitat, Populations, Reproduction and Contaminant Assessment In and Adjacent to the Massena/Akwesasne St. Lawrence River Area of Concern (AOC) for Beneficial Use Impairment (BUI) Advancements

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EXECUTIVE SUMMARY

Data was gathered in and near the Massena/Akwesasne Area of Concern (AOC) to assist with the evaluation of Beneficial Use Impairments (BUI) for avian species in a project funded by a U.S. Environmental Protection Agency (USEPA) grant (GL-97221310) to the St. Regis Mohawk Tribe (SRMT) through the Great Lakes Restoration Initiative (GLRI). A Quality Assurance Project Plan (QAPP) was developed and an Interim Status Report completed to identify data gaps and guide this investigation. Fieldwork was conducted during the spring and summers of 2013 and 2014 to investigate avian habitat, populations, reproduction, and contaminants.

Field surveys of sentinel species were conducted by land and water at sites both inside and outside (upstream and downstream) of the AOC to examine avian populations and reproduction. Nest sites of osprey, herring gull, common tern, and black tern were identified and monitored. The surveys identified osprey, herring gull, and common tern nest in and near the AOC, whereas black tern nests were only found in Snye Marsh of the Mohawk Territory of Akwesasne. The nesting productivity of osprey, herring gull, and common tern was similar inside and outside the AOC. No deformities were observed in osprey, herring gull or black tern chicks. One common tern chick with a crossed bill was found inside the AOC in 2013. This chick was the first common tern chick found with a crossed bill inside the AOC, and the third chick found with a crossed bill during the last 25 years within 25 miles of the AOC of over 16,000 common tern chicks examined. Compared to other areas in the Great Lakes basin, the overall rate of deformities in the Massena/ Akwesasne AOC is low.

Eggs of osprey (n=6), herring gull (n=2, 13-egg composites), and common tern (n=30, 2-egg composites) were collected inside and outside the AOC and analyzed for contaminants of concern including PCBs, mercury, metals, and organochlorine pesticides. Total PCBs were significantly higher in common tern eggs inside the AOC (0.96 ± 0.23 µg/g) than outside the AOC (0.49 ± 0.058 µg/g). The range in PCB concentrations of herring gull eggs was higher (1.03 – 3.93 µg/g) than they were for either osprey or terns. The downstream herring gull egg composite had higher concentrations than the upstream composite sample collected from the Thousand Islands. Mean mercury (Hg) levels were higher in osprey eggs collected inside the

AOC (0.23 ± 0.10 SE µg/g) versus outside the AOC (0.09 ± 0.01 SE µg/g). There were no significant differences in DDE concentrations among the three species inside the AOC as compared to outside the AOC, although common terns had the lowest range of DDE concentrations while osprey and herring gull had similar ranges. There were no significant intra-species differences in the organochlorine heptachlor epoxide inside the AOC versus outside the AOC, but concentrations were lowest in terns, and similar between osprey and herring gull. The range of fluoride concentrations in osprey eggs outside the AOC (17.0 - 23.0 µg/g; n = 3) was higher than the range of fluoride concentrations inside the AOC (ND – 6.3; n =3), but the sample size inside the AOC (fluoride was detected in two of three samples) was insufficient for statistical comparison. No contaminant concentrations in the eggs of these three species were above established toxicity thresholds where adverse effects would be expected.

Population and productivity surveys suggest that osprey and common tern numbers are increasing, in part due to extensive management of nesting sites in and near the AOC, and populations of herring gull and black tern appear to be stable. Habitats inside and outside the AOC are different, and may be limiting for species like common tern in the AOC downstream of the Moses-Saunders Power Dam and for black tern upstream of the AOC at the Wilson Hill Wildlife Management Area (WHWMA). The numbers of nesting pairs of these and other species may be increased through habitat improvement projects in areas where habitat may now be limited.

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LIST OF ABBREVIATIONS

List of abbreviations used in documents related to the Massena/Akwesasne Area of Concern. Not all of the abbreviations listed here appear in this document.

Alcoa	Aluminum Corporation of America
AOC	Area of Concern
BUI	Beneficial Use Impairment (Indicator)
COCs	Contaminants of concern
COSEWIC	Committee and the Status of Endangered Wildlife in Canada
GLNPO	Great Lakes National Program Office
GLWQA	Great Lakes Water Quality Agreement
GM	General Motors (now RACER Trust)
GRLI	Great Lakes Restoration Initiative
HS	Hot Spots
IJC	International Joint Commission
MCA	Mohawk Council of Akwesasne
ND	Non-detect
NTCRA	Non-Time Critical Removal Action
NYPA	New York Power Authority
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OMNR	Ontario Ministry of Natural Resources and Forestry
PAHs	Polycyclic aromatic hydrocarbons
PCBs	Polychlorinated biphenyls
POCs	Persistent organochlorine chemicals
QAPP	Quality Assurance Project Plan
RACER Trust	Revitalizing Auto Communities Environmental Response Trust
RI/FS	Remedial Investigation and Feasible Study
ROD	Record of Decision
SLRRC	St. Lawrence River Restoration Council (Cornwall)
SLRRP	St. Lawrence River Remediation Project (Alcoa East)
SRMT	Saint Regis Mohawk Tribe
SRMTED	Saint Regis Mohawk Tribe Environment Division
USEPA (EPA)	United States Environmental Protection Agency
VOCs	Volatile organic compounds
WHWMA	Wilson Hill Wildlife Management Area

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NYPA and Massena Electric Department provided bucket trucks to access osprey nests and we thank Jeff Gerlach, Sean Doyle, Andrew McMahon, and Dale Raymo for their assistance.

In addition to assistance with permits, data, field notes, and additional information were graciously provided by Chip Weseloh, Dave Moore, Shane de Solla, Doug Crump, and Cynthia Pekarik. Field observations were contributed by Michael Morgan, Blanche Town, James McGarry, Kate Breheny, Bill Munro, Jake Tibbles, Sarah Walsh, and Jay Wilkins. Vegetation surveys were conducted in the field by Anne Johnson with the assistance of Michael Reynolds. Joel Danko, Michael Reynolds, and Anna Butler collected much of the field productivity data for osprey, herring gull, and common tern in 2013 and 2014. Bill Olsen prepared all map figures with the assistance of Lacey Conrad. Earlier drafts of this report were reviewed by Chip Weseloh and Anne Johnson.

The authors express their sincere gratitude to all who contributed to this study.

1.0 INTRODUCTION

1.1 Background and Objectives

The international section of the St. Lawrence River was identified as one of five Bi-National Areas of Concern (AOC) by the International Joint Commission (IJC) under the 1987 amended Great Lakes Water Quality Agreement (GLWQA). The Bi-National geographic boundary is delineated as, "*The St. Lawrence River Area of Concern (AOC) includes the waters from the Moses-Saunders power dam to the eastern outlet of Lake St. Francis, including the area upstream of the Snell lock and power dam to the Massena public water supply intake, the Grasse River from the mouth upstream to the first dam, the Raquette River from the mouth upstream to the New York State Route 420 bridge and the St. Regis River from the mouth upstream to the dam at Hogansburg. This includes water shared by the United States, Canada, and the Mohawks of Akwesasne*" (Environment Canada *et al*. 1994). The boundaries of interest under this Great Lakes Restoration Initiative (GLRI) funded project (GL-97221310) are the upstream and southern portion of the International St. Lawrence River Area of Concern (AOC), primarily located in St. Lawrence County and the Mohawk Territory of Akwesasne (also called the St. Lawrence River AOC at Massena and/or Massena/Akwesasne AOC). The Massena/Akwesasne AOC includes the Grasse (04150304), Raquette (04150305), and St. Regis (04150306) tributaries, Power Canal on the Grasse River, and portions of the St. Lawrence River itself

The Massena/Akwesasne AOC was identified due to discharge of hazardous substances and industrial byproducts to nearby tributaries, land, and the St. Lawrence River itself, thus causing ecological impairments and impaired water quality. Contaminants of concern in the Massena AOC associated with facility releases include: polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), dioxins, furans, cyanide, fluoride, phenols, volatile organic compounds (VOCs), ammonia, styrene, phenols, sulfate, and metals (aluminum, lead, cadmium, and mercury). Organochlorine pesticides of concern in the Massena/AkwesasneAOC include chlordane, dichlorodiphenyltrichloroethane (DDT), dieldrin, endrin, hexachlorobenzene, and mirex. Mercury is also a contaminant of concern in the St. Lawrence River AOC primarily due to contributions from Cornwall, Ontario and some contribution from Massena, NY industry and atmospheric deposition within the watershed.

Several efforts were made to remediate contamination sources and improve water and sediment quality in and around the AOC between 1995 and 2009. Remediation efforts were implemented at the three hazardous waste sites, Alcoa East (Reynolds), Alcoa West, and GM (see remediation summaries below) but the Grasse River remains a source of a large mass of contaminated sediment in the AOC. The United States Environmental Protection Agency (USEPA 2012b, 2013a, and 2013b) has selected a Grasse River remedy to mitigate risks to the biota, fish, human and ecological receptors that includes the dredging of nearshore contaminated sediments and capping of main channel contaminated sediments.

Contaminants in general, and PCBs in particular, can cause a range of adverse health effects in birds, including teratogenic and other reproductive effects, as well as immunological and neurological effects. Responses depend on the species and the particular congener mixture to which that species is exposed, and can therefore vary from subtle (*e.g.*, induction of hepatic microsomal enzymes) to severe (*e.g.*, impaired reproduction and death) (Natural Resource Trustees of the St. Lawrence River Environment 2013). In addition, PCB concentrations are likely to be greater at higher trophic levels due to bioaccumulation and biomagnifications. Dioxin and furan exposure is associated with a wide array of adverse health effects. The PCDDs and PCDFs are similar in physical structure to PCBs and elicit similar responses in birds, including reproductive impairment, edema, thyroid function impairment, and deformities (Hoffman *et al.* 1993).

Data for contaminant levels in avian species in the AOC are generally lacking. In 1987-1988 NYSDEC targeted wildlife for study in the area surrounding the General Motors facility and the Mohawk Territory. Avian species included in that study were primarily waterfowl and species that could be collected opportunistically. No samples were collected in upstream reference areas outside the AOC (NYSDEC 1981, 1990; Skinner 1992).

More recently, avian resources of the AOC area have been found to have elevated levels of PCBs, in waterfowl (NYSDEC 1981, 1990, Skinner 1992), wetland birds (Bishop *et al.* 1995, 1999, Martinovic *et al.* 2003; Champoux *et al.* 2002, 2006, 2010), and colonial waterbirds (*e.g.* Hebert *et al.* 2009). Advisories to limit consumption of certain species of waterfowl due to PCBs and other contaminants have been in place for more than a decade (NYSDOH, various years;

SRMT 2014). For example, the NYSDOH has issued a statewide advisory that recommends avoiding consumption of mergansers and consuming no more than two meals per month of other waterfowl. Similarly, the Saint Regis Mohawk Tribe updated their Game Advisory to include no consumption of waterfowl in specific areas of the St. Lawrence River AOC, such as the Grasse River, Turtle Creek, and Turtle Pond (SRMT 2014). The US Food and Drug Administration (FDA) action level for PCBs in meat is three ppm; concentrations of PCBs in mallard fat were documented up to 613.6 ppm PCBs and in common merganser fat up to 166 ppm PCBs within the assessment area (Natural Resource Trustees of the St. Lawrence River Environment 2013).

The sampling conducted in this study was designed to investigate contaminant burdens in the eggs of selected avian species, including species at higher trophic levels, and the potential effects of these contaminants on their reproduction. Sampling was conducted for contaminants of concern (COC) in the Massena/Akwesasne AOC, including PCBs, pesticides (chlordane, DDT, dieldrin, endrin, hexachlorobenzene, mirex), dioxins, furans, mercury, aluminum, lead, cadmium, and fluoride (Natural Resource Trustees of the St. Lawrence River Environment 2013). The sampling matrix for 2013 avian collections consisted of the eggs of sentinel species that have either not been previously tested from areas within and/or near the Massena/Akwesasne AOC (osprey, common tern) or that have been tested annually (herring gull) (Harper and Jock 2014; Riveredge Associates 2013).

Monitoring of nesting by these species provided current data on populations, habitat, and reproductive success of the selected sentinel species, and comparison was made between inside AOC and outside AOC locations. Additional comparison to existing data of avian tissue analysis and effects-based literature will assist in BUI advancement and delisting efforts.

This study, specific to avian resources of the AOC, is one of several in the Massena/Akwesasne AOC designed to make progress on Beneficial Use Impairments (BUIs) (Table 1). The focus of this study is to make progress on three BUIs: Degradation of Fish and Wildlife Populations, Bird/Animal Deformities or Reproductive Problems, and Loss of Fish and Wildlife Habitat (Table 1).

Criteria established for Degradation of Fish and Wildlife Populations include documentation of healthy and reproducing populations and a community structure that does not significantly diverge from unimpacted sites that would be expected from the amount of quality of suitable physical, chemical, and biological habitat characteristics. The current status of this BUI is "Unknown/Needs Further Assessment" with no surveys conducted to date to compare avian populations inside and outside the AOC. While this project was underway, the Remedial Advisory Committee (RAC) evaluated and revised the delisting criteria for this BUI. The new criteria was approved by the RAC on June 18, 2014 and include the following:

- Concentrations of contaminants (particularly PCBs) in AOC fish and wildlife are not significantly higher than levels found outside of the AOC; OR concentrations of contaminants found in AOC fish and wildlife are below toxicity reference values, established criteria to protect piscivorous wildlife, or adverse effect levels documented in scientific literature.
- Native wildlife species richness and diversity (including resident birds, amphibians, reptiles, and freshwater mussels) in AOC wetland and riverine habitats is equal to or greater than that found in similar habitats in the surrounding region.
- Bald eagle, mink, lake sturgeon, otter, or other sentinel species are present and successfully reproducing in the AOC.

Criteria established for Bird/Animal Deformities or Reproductive Problems within the AOC include documentation that the AOC supports significant species and reports of deformities or other reproductive problems (*e.g.* eggshell thinning) do not exceed background levels from unimpacted sites upriver and outside the AOC. The current status of this BUI is "Unknown/Needs Further Assessment," with no surveys conducted to date to compare avian reproductive productivity or deformities inside and outside the AOC.

Criteria established for the Loss of Fish and Wildlife Habitat include documentation that the amount of habitat is adequate for fish and wildlife management goals and that experts do not identify habitat loss as a cause for non-attainment of these goals. The current status of this BUI is "Impaired," with no surveys conducted to date to compare avian habitat inside and outside the AOC.

Prior to the start of field work, avian sentinel species were identified specific to the Massena/Akwesasne AOC with identified data gaps (Harper and Jock 2014). A Quality Assurance Project Plan (QAPP) was developed with outlined data quality objectives and proposed sampling methodology (Riveredge Associates 2013). Field work was conducted in 2013 and in 2014. Field surveys were conducted of avian sentinel species to investigate habitat, populations, and productivity inside and outside the AOC. In 2014, bird eggs were collected to investigate contaminant burdens in avian sentinel species in and near the Massena/Akwesasne AOC, and the potential effects of these contaminants on avian reproduction. The results of these field surveys are reported in this Status Report.

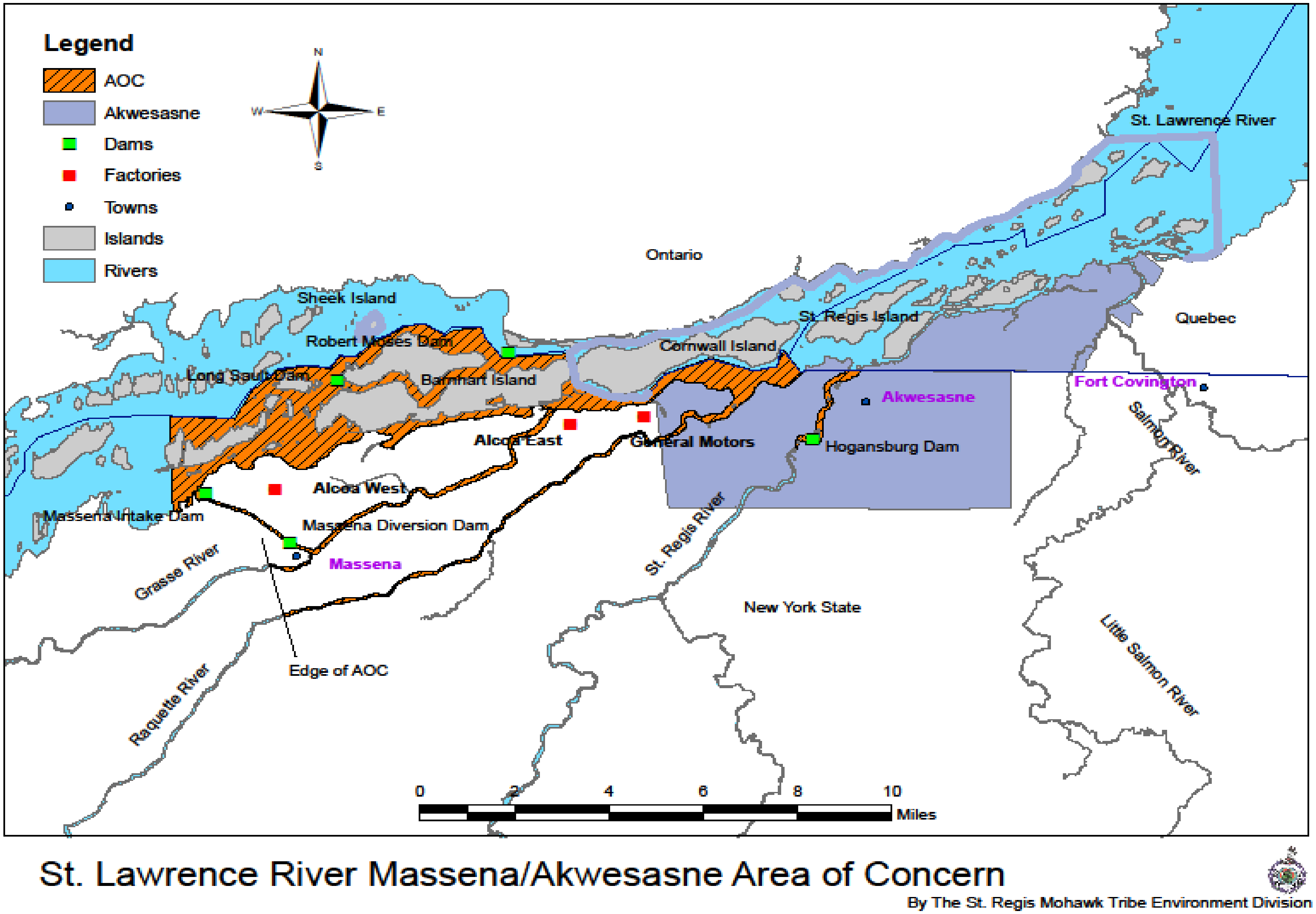

Figure 1. Map of the Massena/Akwesasne AOC.

Table 1. St. Lawrence River, Massena/Akwesasne AOC Beneficial Use Impairments, Status and Delisting Criteria for Fish and Wildlife.

Beneficial Use Impairment	Status	Delisting Criteria	Measurement
Degradation of Fish and Wildlife Populations[1]	Unknown/ Needs Further Assessment	Environmental conditions support healthy, self-sustaining communities of desired fish and wildlife at predetermined levels of abundance that would be expected from the amount and quality of suitable physical, chemical, and biological habitat present; AND Fish populations meet applicable Index of Biological Integrity (IBI) and wildlife populations have healthy reproducing populations of eagle, mink, otter, or other species.	Conduct a qualitative habitat assessment. Use experienced field staff to visually estimate wildlife species presence or absence from observed activity or other field log notes. Use quantitative chemical data of tissue burden to compare to adverse health effects threshold levels
Bird/Animal Deformities or Reproductive Problems	Unknown, Needs Further Assessment	Wetlands support healthy communities of significant species and no reports of deformities from wildlife officials. Exceptions may apply to limited background effects; AND Incidence rates, if present, of deformities (*e.g.* cross-bill syndrome) or other reproductive problems (*e.g.* egg-shell thinning) in wildlife species do not exceed background levels of inland control populations.	Make visual observations of the presence or absence of anomalies or deformities in hatchlings and record on appropriate data sheets for quantification
Loss of Fish and Wildlife Habitat	Impaired	Amounts and quality of physical, chemical, and biological habitat (including wetlands, riparian and submerged aquatic vegetation, and buffers) are adequate for fish and wildlife management goals (achieved and protected); AND Experts do not identify habitat loss as a cause for non-attainment of Fish and Wildlife management goals.	Conduct a qualitative habitat assessment and complete field data forms Use expert field staff to determine if habitat is cause for non-attainment of species in addition to qualitative assessment above.

Notes: [1]Delisting Criteria listed here was used to design study (E&E 2008). Updated criteria was approved by the RAC on June 18, 2014 during the drafting of this report.

1.2 Cultural Significance to Mohawks

Community culture is defined by the wide range of shared and distinct values, attitudes, beliefs, and assumptions people share about themselves and the natural world they live in (USEPA 2002). Understanding the social and geographic boundaries of differing community cultures is important for developing environmental protection of cultural uses, as well as a defined communication strategy when evaluating beneficial uses impairments of a resource of cultural significance. Species of cultural significance have substantial meaning and identity in tribal values and practices including but not limited to: used in family and place names, educational stories, and ceremonies. Adverse impacts (i.e. population decline or chemical body burden) to culturally significant species degrade overall cultural morale and is regarded, equally, as an attack on beliefs and values (Donatuto and Harper, 2008; Garibaldi and Turner, 2004; Harris, 2000).

"Culture is like a tree. If the green branches – A people's language, legends, customs – are carelessly chopped off, then the roots that bind people to their place on earth and to each other also begin to wither. The wind and rain and the elements carry the topsoil away; the land becomes desert."

-*Mariano Lopez, Tzotzil Indian Chamula, Chiapas, Mexico (USEPA 2002)*

Birds play a significant role in Mohawk and Iroquois (i.e. Haudenosaunee) cultural identity in part as depicted in legends, ceremony dance, and clan social structure. The Ohén:ton Karihwatéhkwen (i.e. Thanksgiving Address) details Haudenosaunee perspective on the inter-relatedness and interdependent relationships, respect, and responsibility on and to all parts of the natural world and amongst creation (ATFE 2001). The Ohén:ton Karihwatéhkwen expresses that the birds were gifted to us by the Creator to remind us to enjoy and appreciate life, flying over our heads, with beautiful song; while some were provided to us as food. The eagle was chosen as the leader of the birds, in part because it can fly the highest and has ability to see all of creation. The eagle is a culturally significant species to Haudenosaunee as a symbol of strength and teachings (i.e. behavioral; cooperative rearing between mother and father, providers, bravery, warning, and messenger to Creator). Its feathers are used in Kastow:as (traditional headdress worn by men in ceremony), and ceremonial and Powwow regalia (Photo 1; See Akwesasne International Powwow Photo Gallery at http://www.akwesasnepowwow.com/photos.htm). Feathers from other birds such as hawks, turkeys, and geese are also used in traditional dress and ceremony. Some social songs and dance specific to birds include the duck dance, robin dance, pigeon dance, and rooster dance (see YouTube Hotinonhsonii Social Dances Part 1-5; Mckenzie, 2008, 2009).

The Mohawk territory name, Akwesasne, translates to ‘where the ruffed grouse are at’ or also known as “where the partridge drums” (partridge referring to ruffed grouse, and drumming refers to the male ruffed grouse’s signature spring courtship sound). The word for ruffed grouse and partridge are similar in Kahniakeha; the Mohawk language. Other notable species include the great blue heron, snipe, and hawk as they are clan birds in the Haudenosaunee Clan System. Clans are matrilineal, family units in a Nation, and Clan Mothers and Chiefs are responsible for the matters of the people, consistent with the principles of The Great Law and Ohén:ton Karihwatéhkwen. The loon is also mentioned as a great source of medicine in Handsome Lake prophecies, and is respected as an intermediary between Onkwehón:we people and the Thunder Beings (NAITC 1984,2007; LaFrance, A. et al., pers. comm, 2015).

Many Haudenosaunee legends and stories feature birds. Two pivotal legends involving birds include the Creation Story (i.e. swans, geese, or great blue herons depending on the interpretation caught SkyWoman as she fell), and the story of the Iroquois hero; Hiawatha (Aionwá:tha) (LaFrance, A. et al., pers. comm.2015). While Hiawatha was traveling through the Territory of the Mohawks, he came to the edge of a great lake. As he was wondering how to cross it, a huge flock of ducks descended on the lake and began to drink the water. When the birds rose up again, the lake was dry and its bed was covered with shells. From these shells, Hiawatha made the first Wampum beads and used them as a symbol of condolence and peace to unite the tribes (Cayuga, Oneida, Onondaga, Mohawk, and Seneca) in Confederacy. Known today as the Iroquois or Haudenosaunee (First People http://www.firstpeople.us/FP-Html-Legends/The-Wampum-Bird-Iroquois.html).

Photo 1. Mohawk kastowa (pronounced gustoweh) made of bird feathers (eagle and hawk feathers displayed in top photo). Mohawk kastow:as have 3-eagle feathers straight up, on top. Bottom photo taken at 2011 Akwesasne Powwow (photo credit Tribal Vision Dance.com).

1.3 Avian Sentinel Species of the AOC

In the Great Lakes, sentinel species used to monitor contaminants have included bald eagle (*Haliaeetus leucocephalus*), osprey (*Pandion haliaetus*), herring gull *(Larus argentatus)*, common tern (*Sterna hirundo*), great blue heron (*Ardea herodias*), black-crowned night-heron (*Nycticorax nycticorax*), tree swallow (*Tachycineta bicolor*) and others (Karwowski, 1992; Bishop *et al.*, 1995; Bishop *et al.*, 1999; Fox, 2001; Martin *et al.* 2003; Martinovic *et al.* 2003; Champoux *et al.*, 2002, 2006, 2010; Szczechowski *et al.*, 2009; Hughes *et al.* 2010; Mayer *et al.*, 2011; Weseloh *et al.*, 1989, 2011; Baird *et al.*, 2012; Custer and Custer, 2013).

Three sentinel species of interest to the Massena/Akwesasne AOC for evaluation in this study as identified by Harper and Jock (2014) areosprey, common tern, and herring gull. Osprey is an excellent sentinel species for contaminant monitoring and has been used for this purpose worldwide (Grove *et al.* 2009). The common tern is the only Great Lakes waterbird indicator species that breeds in significant numbers inside and outside the Massena/Akwesasne AOC (Harper and Jock 2014). Terns which breed in the AOC are known to have elevated mercury levels in feathers, although individual variance is high (Baird *et al.*, 2012). Contaminants in common terns have been examined in other areas (French *et al.*, 2001; Mierzykowski, 2008) and terns have been (or are being) used as an indicator species in the Great Lakes (Weseloh *et al.*, 1989) and on the Detroit River-Western Lake Erie Basin Indicator Project (Szczechowski *et al.*, 2009). Contaminants in Great Lakes herring gulls have been monitored by the Canadian Wildlife Service for over 30 years and herring gull eggs have been used as an indicator of contaminant levels in the Cornwall AOC since 1986 (Herbert *et al.*, 2009). Herring gulls that nest adjacent to the AOC forage inside both the Cornwall AOC and the Massena/Akwesasne AOC. In addition to these three species, black tern (*Chlidonias niger*) was selected for productivity monitoring (but not egg collection) because of its rarity in the region (it is an endangered species in New York), known presence on Akwesasne Territory and because no recent nest counts or productivity records exist for this species in this area.

Table 2. Avian species occurring in and near the AOC and their conservation status. E=Endangered, T = Threatened, V= Vulnerable, SC = Special Concern, P=Protected.

Scientific Name	Common Name	New York Status[2]	Species of Greatest Conservation Need (SGCN) in New York[3]	Akwesasne Species at Risk Birds[4]	Ontario Status[5]	Quebec Status[6]
Haliaeetus leucocephalus	Bald eagle	T	✓	Sensitive	Special Concern	
Pandion haliaetus	Osprey	SC	✓			
Ardea herodias	Great blue heron	P				
Larus argentatus	Herring gull	P				
Sterna hirundo	Common tern	T	✓	Sensitive		
Chlidonias niger	Black tern	E	✓	Sensitive	Special Concern	Sensitive
Aquila chrysaetos[1]	Golden Eagle	E	✓	E	E	V

Notes:

1. This species recently anecdotally reported as occurring in the AOC in Akwesasne but further research needed. .
2. New York Status: http://www.dec.ny.gov/animals/7494.html
3. SGCN Status: http://www.dec.ny.gov/docs/wildlife_pdf/sgnc2015list.pdf
4. Based on Mohawk Council of Akwesasne (MCA) designation
5. Ontario Status: https://www.ontario.ca/environment-and-energy/species-risk-ontario-list
6. Quebec Status: http://www3.mffp.gouv.qc.ca/faune/especes/menacees/liste.asp

1.4 AOC Remediation Summaries

1.4.1 General Remediation Summary

A principal goal of the *Revised Great Lakes Water Quality Agreement of 1978, as amended by Protocol signed November 18, 1987* (1987 GLWQA) is to restore the chemical, physical, and biological integrity of the Great Lakes Ecosystem in the Areas of Concern (AOCs) (IJC 1987). Primary contaminants of concern in the Bi-National St. Lawrence River AOC include: polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), chlorinated pesticides (including mirex and hexachlorobenzene), dioxins, furans, and metals (Environment Canada *et al*. 1994).

While many remedial successes and contaminant mass reductions (i.e. PCBs, PAHs, dioxins, and metals) have contributed to the restoration of the Massena/Akwesasne AOC since 1995 on the United States side, excessive levels and inventory of PCBs can still be found in sediments in the Grasse River Superfund Site. Fish tissue concentrations are elevated, and fish and wildlife advisories are still in effect in the Massena/Akwesasne AOC. Health risks to Mohawks have been identified through epidemiological studies and subsistence/cultural exposure routes, and NYSDOH had issued a Special Consumption Advisories for the Akwesasne Mohawk Nation specific to lake sturgeon and other game consumption (Forti *et al*. 1995).

Between 1995-2013, a number of remedial efforts have taken place at the Massena, NY Industrial facilities (i.e. Alcoa West, RACER formerly known as General Motors, and Alcoa East formerly known as Reynolds Metals) to contribute to reduction of contaminant mass and/or exposure, contaminated fish tissue concentrations and its associated human and ecological risk reduction, and ecological restoration. The land-based remediation of eighteen contaminated sites at Alcoa West and six contaminated sites at Alcoa East (former Reynolds Metals) was completed in 2001, and fulfills the requirements of the two 1992 Record of Decisions (RODs) for these sites. GM land remediation and demolition for revitalization was conducted by RACER Trust (http://www.racertrust.org/files/massena-marketing-brochure.pdf). Plant demolition began in 2011 and completed in 2014. Remediation of site sources is to be completed in 2015. Long-term groundwater remediation and monitoring of the “GM Dump” is underway.

1.4.2 Site specific Remediation Summaries

St. Lawrence River – Alcoa East Plant (Formerly Reynolds Metal Company (RMC))

Through 1989-1992 remedial investigations and feasibility studies (RI/FS) of the St. Lawrence River adjacent to Alcoa East were conducted with PCB-contaminated sediments identified as the primary contaminants of concern (COCs). Other contaminants identified as present at the site included furans, fluoride, aluminum, cyanide, and PAHs found in similar patterns of PCBs at this site on the St. Lawrence River. USEPA issued a 1993 Record of Decision (ROD) that called for dredging of sediments containing contaminants in excess of 1mg/kg (ppm) PCBs, 10 mg/kg total PAHs, and 1 ug/kg (ppb) of total dibenzofurans (TDBFs). This area of contamination was 21.8 acres. In 2001 the St. Lawrence River Remediation Project (SLRRP) dredging commenced following those prescribed clean-up goals to remove 86,000 cubic yards (cy) of contaminated sediments (20,200 lbs of PCBs) in a dredge design divided into 268 “dredge cells” (avg. 0.08 acres each). The ROD estimated 28% of the contaminated sediment inventory on-site included PCBs ≥ 25 mg/kg, with 9 identified Hot Spots (HS) Units delineated into 0.06 acres (2,500ft^2 areas) with PCBs ≥ 500 mg/kg (USEPA 1993, USEPA 2008, USEPA 2012a).

After completion of 2001 dredging efforts, post-dredging verification sampling demonstrated a site-wide average PCB concentration of 0.8 mg/kg PCBs, a 98.6% PCB contaminant reduction. All but 12 of the 268 dredge cells achieved target PCB clean-up goal of 1.0 mg/kg PCBs; those 12 cells were capped in 2009 to achieve assumed 100% PCB clean-up goal achievement for risk reduction.

A 90% reduction in PAHs was achieved in 2001, and additional verification sampling conducted between 2002-2006 indicated 76 of the 268 dredge cells were above the 10 mg/kg total PAHs clean-up goal. Fifty-three dredge cells indicated total PAHs >20 mg/kg with a maximum concentration detection at D-118 of 741 mg/kg in fall 2002. In addition to dredge cell D-118, 5 additional dredge cells indicated > 100 mg/kg total PAHs at 285, 241, and 244, 181, and 112 mg/kg for dredge cells A-7, A-16, C-39, D-117, and D-126 respectively. All 53 dredge cells with PAHs> 20 mg/kg were capped in 2009. Twenty-three cells indicated PAHs between 10-20 mg/kg, and these were assumed to have naturally degraded with time due to low molecular weight PAH degradation period (~3years) (USEPA 2008).

On the 21.8 acre contaminated site, 3.5 acres were capped for achievement of risk reduction goals associated with PCBs and total PAHs. A 100% achievement of clean-up targets for TDBFs was achieved via 2001 dredging and 2009 capping (USEPA 2008).

St. Lawrence River –Former General Motors, Central Foundry Division (GM)

The USEPA issued a Record of Decision for the General Motors (Central Foundry Division) for Operable Unit 01 in December 1990. The ROD outlined several major areas for soil remediation of the North and East disposal areas and industrial landfill; sludge and liquid remediation in four unlined industrial lagoons (350,000 gallon, 500,000 gallon, 1.5 million gallon, and 10 million gallon lagoons); contaminated sediments, riverbanks, and associated wetlands of the St. Lawrence River, Raquette River, and Turtle Creek; and contaminated Tribal property and contaminated groundwater (with groundwater flow north and northeast to the St. Lawrence River and Turtle Creek, respectively). Contaminants of concern identified during the 1988 RI/FS at the GM Site include PCBs, PAHs, phenols, and volatile organic compounds (VOCs). PCBs were detected at highest concentrations and frequency, and therefore drove remediation at this site (USEPA 1990).

The ROD identified over 62,000 cy of contaminated river sediments and soil with PCB concentrations above 1 mg/kg located in and along the St. Lawrence River, Raquette River and Turtle Creek (with majority of contaminated sediments ~56,000 cy in St. Lawrence River adjacent to the facility) (USEPA 1990).

During RI/FS the highest concentration of PCBs detected was 5,700 mg/kg, and PAHs up to 8.0 mg/kg. The 1995 dredging activity on the St. Lawrence River removed 18,000 cy of contaminated sediment. A 1.72-acre cap was placed over the areas that did not achieve the 1.0 mg/kg PCB clean-up goal (USEPA 2013c, 2015)

General Motors, Raquette River and bank soils

During RI/FS the highest PCB concentration detected in the Raquette River was 390 mg/kg. In 2002, river bank and sediment removal efforts removed 11,000 cy of soils and 1,400 cy of sediment with respective 10 mg/kg PCB and 1.0 mg/kg PCB clean-up goals successfully achieved.

General Motors, Turtle Cove and associated wetlands/uplands

During RI/FS, approximately 15,000 cy of soil >1 mg/kg PCBs was identified to be located on adjacent Tribal Mohawk Property (highest concentration reported of 48 ppm). NYSDEC detected PCBs concentrations as high as 3,101 mg/kg in Turtle Creek, with at least 4 samples >100 mg/kg PCBs (USEPA 1990).

In 2003, 4,600 cy of highly contaminated soils between the Northeast Industrial Landfill and the Cove were removed. By spring 2005, 18,000 cy of PCB-contaminated sediment and soils from the cove area were excavated in the dry to achieve Mohawk clean-up standard of 0.1 mg/kg PCBs. The sediment clean-up goal was based on the 1989 Saint Regis Mohawk Tribal Council Resolution (No. 89-19) promulgated sediment standards for Mohawk territory protection of human and ecological health.

An estimated 700 cy of soils still need to be remediated on Mohawk Upland Properties (soils) with a clean-up goal of 1.0 mg/kg PCBs. Historic samples range from 1.0-10.0 mg/kg PCBs.

Grasse River – Alcoa West Plant

USEPA issued an Administrative Order to ALCOA, Inc. in September 1989 to investigate the nature and extent of hazardous toxic material in the lower Grasse River, Unnamed Tributary, Robinson Creek, and the Power Canal. The lower Grasse River underwent remedial investigation and feasibility studies (RI/FS) from 1990-2013 when a Record of Decision (ROD) was issued in April 2013. Remedial design and pre-monitoring was proposed for 2014, with implementation expected in 2015-2020 (USEPA 2013a).

In 1995, EPA required Alcoa to conduct a Non-Time Critical Removal Action (NTCRA) due to significantly elevated PCB sediment concentrations in the lower Grasse River identified adjacent to Outfall 001. Removal of ~3,000 cubic yards (cy) of contaminated sediment, boulder, and debris comprising of PCB concentrations ranging from 12 mg/kg-11,000 mg/kg, representative of about 20% (8,000 pounds (lbs)) of the total PCB mass in the river was conducted. PCB average sediment surface concentrations were reduced from 518 to 75 mg/kg (1.1-260 mg/kg range post-dredge sampling) in 1995 (BBL 1995, USEPA 2012b, USEPA 2013a).

In 1998, 10,650 cy of PCB-containing sediments were removed from the Unnamed Tributary, and disposed of in the on-site Secure Landfill.

In most years from the mid-1990s until currently, water column monitoring in the lower Grasse River has been conducted spring through fall. Data trends indicate seasonal patterns with highest concentrations in summer, and lowest in late fall and noticeable decreases over the years (i.e. 115-130 ng/L (ppt) in the mid-90s to 8-20 ng/L in 2011 with background concentrations of 0.2-3.0 ng/L). Power canal concentrations averaged 7.9 ng/L in 1998 and 1.9 ng/L in 2002 (USEPA 2012b).

In 2005, a Remedial Options Pilot Study (ROPS) was conducted to evaluate cost and implementation feasibility of multiple remedial options. An 8-acre area was targeted by Transect 7 (T7) for main channel dredging of sediments ranging from non-detect (ND) to 3,668 mg/kg PCBs (with highest concentration at 3.5 ft sediment depth, and a pre-dredge average surface concentration of 3.8 mg/kg). A maximum volume of 75,000 cy was proposed for removal. Of that, only 24,400 cy was removed, with 84% of PCB mass targeted successfully removed, but with increased post-dredge average surface concentrations (138 mg/kg) due to difficulty from debris and/or hard bottom preventing access to clean underlying material. This area was capped, with post-cap average concentrations of 7.4 mg/kg, a 95% reduction in post-dredge conditions (Alcoa 2005, 2006).

Additional river sediment investigations conducted 1995-2010 identified highest PCB concentrations at depth, and widely distributed throughout the 7.2 river mile stretch. Current conditions indicate approximately 1.7 million cy of sediment with PCBs ≥ 1mg/kg over a 325 acre area exist as remaining inventory in the lower Grasse River (USEPA 2012b). The 7.2 river mile study area is broken down by 0.1 mile transect (T1-T72), and main channel and nearshore (water depths of five feet or less during normal summer flow). Current PCB-laden sediment concentration ranges are summarized below:

- ND-3,106 mg/kg PCBs in the Main Channel (T1-T21),
- ND-3,070 mg/kg PCBs in the Nearshore (T1-T21),
- ND-1,063 mg/kg PCBs in Main Channel (T21-T72),
- ND- 313 mg/kg PCBs in the Nearshore (T21-T72)

The 2013 Record of Decision by USEPA calls for: 109,000 cy of nearshore PCB-contaminated sediment ≥ 1 mg/kg to be removed, with clean back-fill to grade for nearshore T1-T72 (7.2 miles); a 59-acre armored cap within the upper 2-river miles; and over 225-acres of sand/natural cap over remaining 5-river miles of main channel with PCB concentrations ≥ 1mg/kg.

Site-wide remedial action is based on PCBs only, however initial sediment investigations for Baseline Ecological Risk Assessment also detected VOCs, PAHs, dioxin, furans, aluminum, arsenic, fluoride, and lead in lower Grasse River sediments at variable concentrations and locations (TRC 1993). Due to the widespread distribution of PCBs throughout the site, it's assumed that by remediating the PCB contamination, all other contaminants bioavailable at site will be remediated as well. EPA established several remedial action objects. These included a 0.01 mg/kg PCB fish tissue remedial goal designed to be protective of Mohawk health from fish ingestion for the lower Grasse River (USEPA 2013a), and minimize PCB bioavailability of PCBs in sediments to the biota (including benthos such as freshwater mussels).

2.0 METHODS

2.1 Study Area

The Investigation Area included the Massena/Akwesasne AOC and wetlands, rivers, and other habitats adjacent to the AOC both upstream and downstream. Potential survey and sampling locations included known nesting locations of these species as identified in the Interim Status Report (Figure 2) (Harper and Jock 2014). These areas included sites well upstream of the AOC in the Thousands Islands Region as well as sites downstream of the AOC in Lake St. Francis. Common tern nesting locations were well documented and occur on Lake St. Lawrence (Figure 3). Bald eagle nest site locations are not mapped in accordance with NYSDEC policy due to concern over the sensitivity of this species.

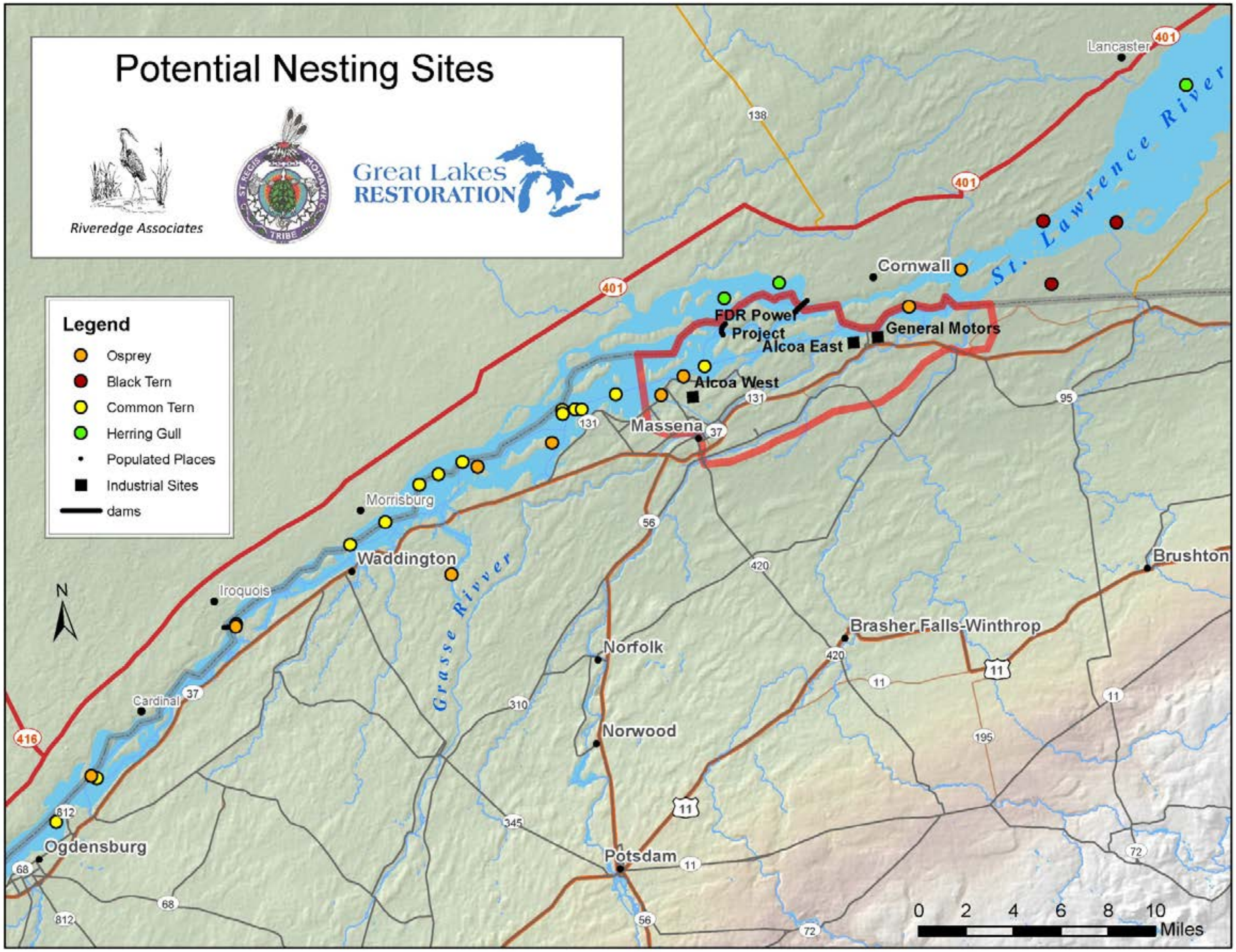

Figure 2. Map of potential avian nesting sites identified in Interim Status Report.

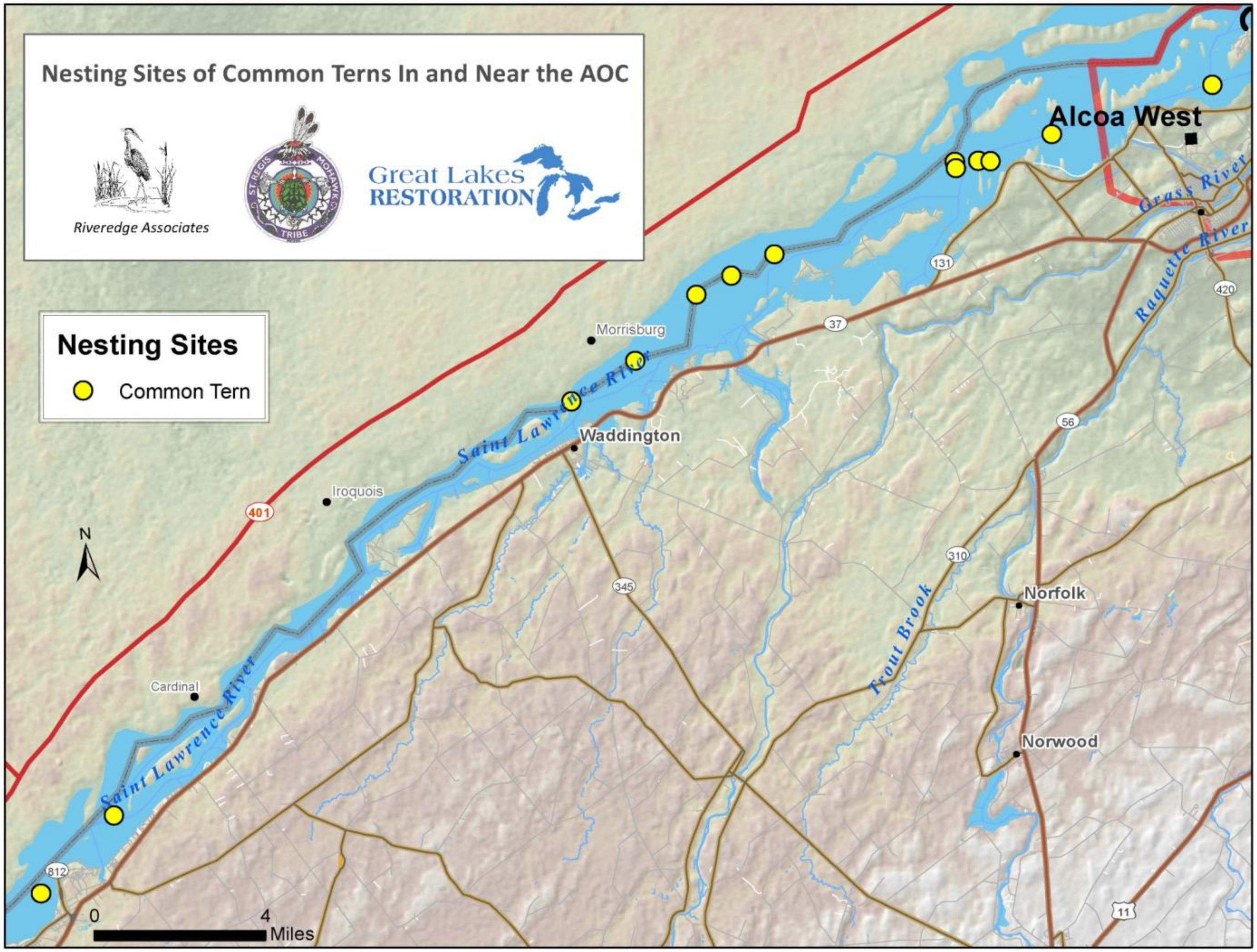

Figure 3. Map of Lake St. Lawrence common tern colony locations.

2.2 Preparation of Quality Assurance Project Plans

A Quality Assurance Project Plan (QAPP) was prepared for this investigation. The project tasks outlined in the QAPP included:

1. Reconnaissance surveys conducted in the early spring (May) of habitat within the AOC and appropriate and comparable reference locations outside AOC to obtain qualitative information on habitat, and confirm appropriate sampling sites.
2. Collect egg samples for contaminant analysis from the AOC and reference sites from herring gull, osprey, and common tern during May and June and submit them for chemical analysis.
3. Chemical analysis of individual osprey eggs and species and site specific composite egg samples of herring gull eggs and common tern eggs by Pace Analytical for PCB congeners, mercury, pesticides, dioxin/furans, metals, and fluoride.
4. Make observations of habitat, populations, and reproduction during the breeding season.
5. Make observations of external abnormalities in common tern chicks and black tern chicks that nest on the ground and are accessible.
6. Determine productivity (number of chicks fledged per nest) for avian sentinel species inside and outside the AOC (where they occur) for bald eagle, osprey, common tern, and black tern.

The Specific Project Objectives identified in the QAPP included:

1. Determine contaminant concentrations (PCBs, organochlorine pesticides, mercury, other metals, fluoride, and dioxin/furans) in the eggs of species nesting within foraging distance of the AOC including herring gull, osprey and common tern.
2. Compare contaminant concentrations in herring gull, osprey and common tern inside the AOC (or that forage inside the AOC) to reference locations outside the AOC (outside of foraging range).
3. Compare contaminant concentrations in avian eggs to published literature, including toxicity reference value thresholds.
4. Assess the presence of any anomalies or deformities in selected species (*e.g.* club foot or crossed bill on common terns or black tern).
5. Conduct an assessment and comparison of habitat, populations, and productivity (chicks fledged per nest) for selected sentinel species inside AOC and outside AOC.

The original schedule for field work anticipated all activities to occur in 2013. However, due to permitting issues, egg collection could not be conducted until 2014. Observations of nesting and productivity were conducted in 2013 and again in 2014.

2.3 Field Survey Methods

For population, habitat, and reproduction (productivity) surveys, nesting sites were identified from the Interim Status Report (Harper and Jock 2014) and from conducting surveys of the rivers inside the AOC, upstream of the AOC, and downstream of the AOC. Identified nesting sites of bald eagle, osprey, herring gull, common tern, and black tern were surveyed at sites where they occurred inside and outside the AOC. New sites were located during searches of the rivers by boat and of the shorelines by vehicle. Data collected at each nesting site included GPS coordinates, approximate size of nesting site, whether the site is natural or artificial, substrate of the site, type of vegetation, number of eggs and/or chicks present on the survey, and distance from shore if on an island. Each site was visited several times during the nesting season to count eggs and chicks to calculate the productivity of the birds nesting at each site. For nests that were difficult to access (*e.g.* osprey nests on poles), binoculars or a spotting scope were used to conduct observations. Productivity at some sites (*e.g*. bald eagle) was monitored by staff of the New York State Department of Environmental Conservation where access was restricted or additional disturbance was not warranted. Productivity was calculated by counting the number of chicks per nest that fledged.

2.4 Contaminant Sample Collection Methods

For egg collection, state, federal and tribal permits were obtained before collection began. Nesting sites were visited in early spring to determine which individual nests were occupied and which birds were actively incubating eggs. Osprey nests on land on poles and platforms were accessed by bucket truck. Osprey nests on navigation structures were accessed by boat. Common tern and herring gull colonies were all accessed by boat. One egg was collected from each nest using nitrile gloves in accordance with the Standard Operating Procedures (SOPs) detailed in the QAPP (Riveredge Associates, 2013). Eggs were then placed in a whirlpack that was labeled with the specimen ID number, location, date, and time the egg was collected. The eggs were carefully wrapped in bubble wrap and placed in a plastic container inside a cooler with ice. A field sample collection form was filled out and stored with the sample. Eggs were taken to the lab where they were opened and the contents extracted. Samples were kept frozen until shipped to Pace Analytical Laboratories for analysis.

The location of all sample collections was recorded in the field with a Garmin GPS 76 handheld global positioning receiver or determined from Google Earth.

The thickness of all eggshells was measured with a Mitutoyo digimatic micrometer to the nearest 0.001 mm. Measurements were taken three times at each of three locations near the equator of the shell and averaged.

3.0 RESULTS AND DISCUSSION

3.1 Achievement of Objectives

The sampling objectives for contaminant sampling proposed in the QAPP were 30 samples for common tern, six samples for osprey, and two composite samples for herring gull (Table 3) (Riveredge Associates 2013). These sampling quality objectives were achieved. Since no common terns were found nesting in the AOC below the Moses-Saunders Power Dam, 15 samples were collected from each of two locations instead of 10 samples from three locations. This potential issue was anticipated and outlined a priori in the QAPP (Riveredge Associates 2013). Due to agency concerns over the potential impacts of collecting too many eggs of common tern, samples were only two egg composites instead of the originally proposed three egg composites. This reduced sample mass and limited the number of analyses that could be performed.

The QAPP proposed a number of potential sampling and survey locations based on the Interim Status Report (Harper and Jock 2014). For egg sample collection, eight potential sites were listed for osprey, six for herring gull, and four for common tern. The sites of egg collection for herring gull and common tern were the sites identified in the QAPP. For osprey, some of the sites identified in the QAPP did not have nesting ospreys when egg collection was conducted in 2014, and new, previously unidentified sites did have nesting birds. Four of the sites were previously identified, and two sites were new. Of the two new osprey sites, one was in the AOC and one was at an upstream reference location (Thousand Islands). The new site in the AOC was less than 1 km from the proposed site. The new upstream reference site was 8 km upstream of the proposed site.

Table 3. Target species and number of egg sample collections proposed in QAPP.

Species	Number of Samples			
	Upstream Outside	Inside AOC	Downstream Outside	Total
Common Tern	10	10	10[2]	30 samples from 3 sites [1,2]
Osprey	3	3	0	6 samples from 6 sites [3]
Herring Gull	1	1	1	3 composite samples from 3 sites [4]
Total Samples	14	14	11	39

[1] Two-egg composites

[2] If no downstream sites for common tern are found, the number of samples from inside AOC and upstream of the AOC will be increased to 15 inside the AOC and 15 outside the AOC at an upstream location.

[3] Osprey samples will not be tested for dioxins/furans due to sample mass limitations

[4] The inside the AOC site will be Strachan Island, where CWS has collected eggs annually since 1986 to monitor the Cornwall AOC. Herring gulls nesting at Strachan forage inside the Massena/Akwesasne AOC as well.

3.2 Species of Birds Inside and Outside the AOC

During the literature review conducted during the preparation of the Interim Status Report (Harper and Jock 2014) and the Quality Assurance Project Plan (Riveredge Associates 2013) avian sentinel species were considered for study inside and outside the AOC. Few sentinel species are known to nest both inside and outside the AOC, especially in areas that are accessible and easily monitored or sampled.

The four species selected for this study were the osprey, herring gull, common tern, and black tern (Table 4) (Harper and Jock 2014). Nesting sites were identified through a literature search, review of personal field notes, discussions with knowledgeable individuals, and through field searches conducted in 2013 and 2014. Nesting sites were surveyed to determine their habitat characteristics and the number of nests at each site. Nests were monitored to determine average productivity, and eggs were collected at selected sites to determine contaminant burdens in osprey, herring gull, and common tern.

In some cases, nesting sites were immediately adjacent to the Massena/Akwesasne AOC, such as at Strachan Island and Bergin Rocks where herring gulls nest upstream of the Moses-Saunders Power Dam and immediately adjacent to the Massena/Akwesasne AOC. These nests are considered inside the AOC because the AOC is within the foraging range of these birds. Osprey nests and black tern nests located in Snye marsh were categorized as downstream the AOC because of their location immediately downstream of areas of contamination of the Massena/Akwesasne AOC. Black tern nests were monitored because of their rarity in the region (they are an endangered species in New York) and because productivity data were lacking. Both common terns and osprey were known to nest inside and upstream the AOC, with osprey also nesting downstream the AOC. Theproductivity and contaminant burdens of these species were determined in this study by collecting and analyzing eggs.

Table 4. Bird species selected for this study.

Species	Nest Sites Outside and Upstream of AOC?	Nest Sites Inside AOC?	Nest Sites Outside and Downstream of AOC?
Osprey	Yes	Yes	Yes
Herring Gull	Yes	No, but nest at Strachan Is. and Bergin Rocks adjacent to AOC and these birds forage inside the AOC	Yes
Common Tern	Yes	Yes	No, historical records only
Black Tern	No, historical records only for Wilson Hill Wildlife Management Area	No	Yes, in Snye Marsh on Mohawk Territory

3.3 Habitat and Populations Inside and Outside the AOC

Avian nesting habitats and populations were assessed inside and outside the AOC by searching for active nesting sites along each river by vehicle and boat. Common tern and herring gull colonies were accessed by boat. Osprey nests were accessed by boat or vehicle, and those nests on poles and platforms were observed with spotting scopes and binoculars. Black tern nests were accessed by boat, canoe, kayak and/or by wading into the nesting areas. At each active nest site, standardized field data sheets were completed. Data collected at each nesting site included GPS coordinates, approximate size of nesting site, whether the site was natural or artificial, substrate of the site, type of vegetation (if any), number of eggs and/or chicks present, and distance from shore if the site was on an island. Each site was visited several times over a period of several weeks and egg and chick counts were done each time to calculate the productivity of the birds nesting at each site. Productivity was calculated by counting the number of chicks per nest that fledged at each site for each species.

Osprey: The population of ospreys on the St. Lawrence River has increased over the last 25 years (Lee Harper, personal observation). In 1990, there was only a single osprey nest on the St. Lawrence River from upstream of Clayton, New York to the Moses-Saunders Power Dam at Massena, a distance of approximately 85 miles. This nest was located on an abandoned navigation cell tower between Alexandria Bay and Chippewa Bay. The first notable expansion of the osprey population on the St. Lawrence River was related to the first installations of osprey nesting poles and platforms. In 1991, the Ontario Ministry of Natural Resources installed five osprey nesting platforms in the Thousand Islands region, and all five were occupied in the first year (Lee Harper, personal observation). Over the next decade the number of osprey nests increased and osprey nests started to appear further downstream. Osprey are now common upstream, inside, and downstream of the AOC. Inside the AOC and upstream of the AOC, virtually all known osprey nests are on poles and platforms or on navigation cells, power poles, cottage chimneys, or other man-made structures (Photo 2). Osprey often choose to nest on artificial platforms over trees when both are available. Osprey often choose nest sites that stand apart from neighboring trees to provide good visibility around the nest, ease of entry and exit, and as a safe guard against predators. There is one nest known in the Thousand Islands region that is on the ground of a small island, but it was not active in 2013 or in 2014. Osprey nests usually measure approximately 3 feet by 3 feet. Nests may be reused each year and additional sticks added. Old nests can be very large. Our field observations indicate that osprey have no preference for any species of tree.

A total of 19 osprey nests was monitored during 2014. Of these 19 nests, 10 were outside and upstream of the AOC, three were inside the AOC, and six were outside and downstream of the AOC (Table 5). All 10 nests outside and upstream of the AOC were on artificial structures. Inside the AOC, all three nests were on artificial structures. Outside and downstream of the AOC all six nests were on natural structures (trees or tree stumps). The characteristics of nesting sites and their relation to the AOC are summarized in Table 5. Individual sites are listed in Table 6.

The 19 osprey nests monitored in 2014 on islands inside and outside the AOC were located from 17 meters to 3,200 meters (0.1-2.0 miles) from the mainland (Table 5, Table 6). Upstream of the AOC in the Thousand Islands, all nests were on artificial structures located on large islands (14-185 acres) ranging from 800 meters to 3,200 meters (0.5 to 2.0 miles) offshore of the mainland (Table 5, Table 6). Nests on Lake St. Lawrence were all on artificial nesting platforms or navigation structures, and most were on the mainland. In the Snye Marsh, all nests were located on natural features such as tree stumps or fallen trees.

Of the 19 osprey nests included in this study only 31.6% (n=6) nested in or on trees or tree stumps, the remaining 13 nests were on artificial sites. Nesting habitat outside and upstream of the AOC consists almost entirely of manmade platforms. No osprey nests outside and upstream of the AOC in 2013 and 2014 were on natural structures such as cliffs or trees. Inside the AOC, osprey nests are located on both manmade structures and in trees. In the Snye Marsh, most nests are fallen trees or on tree stumps located 400 to 2,000 meters (0.25 to 1.25 miles) from the mainland (Table 5).

The osprey nests on the natural islands of Snye Marsh contained the most varied vegetation. Islands supporting osprey nests were characterized by a dense, tangled thicket of vegetation consisting primarily of sumac (*Rhus typhina*) crack willow (*Salix* cf. x *fragilis*), and round leaved dogwood (*Cornus rµgosa*) heavily covered with grape (*Vitis riparia*), Virginia creeper (*Parthenocissus vitacea*), and virgin's bower (*Clematis virginiana*) vines along the shores. Basswood (*Tilia americana*) was the dominant tree species on all of the islands (both along the shores and in the interiors), with hickory (*Carya* sp.), white oak (*Quercus alba*), dotted hawthorn (*Crataegus punctata*), elm (*Ulmus* *americana*), and maples (*Acer rubrum* and *saccharinum*) as secondary components. The island shores were generally rimmed by large rocks with scattered woody debris. The interior of the islands appeared similar to the edges, though with less sumac cover and more herbaceous cover in places. Herbaceous vegetation typical of all islands consisted of jewelweed (*Impatiens capensis*), nettles (*Urtica dioica*), and goldenrods (*Solidago* spp.). Elderberry (*Sambucus canadensis*), alder (*Alnus incana*), and purple loosestrife (*Lythrum salicaria*) are common secondary shrubby and herbaceous species.

The New York Power Authority (NYPA) is conducting the Osprey Nesting Platform Habitat Improvement Project (HIP) on Lake St. Lawrence. This project is installing osprey nesting poles and platforms along the shoreline between Massena and Lisbon (upstream AOC). To date, seven platforms have been installed out of theoriginal goal of 10 platforms.

Osprey are one of the few sentinel species that have good populations and plenty of nesting habitat inside and outside the AOC. Osprey are used as an indicator species for contaminants worldwide (Grove *et al.* 2009).

Table 5. Summary of habitat characteristics of osprey nesting sites inside and outside the AOC.

Location	Number of Sites	Number of Natural Sites	Number of Artificial Sites	Island or in Water	Island Area (acres)	Distance to Mainland (meters)
Upstream of AOC (Lake St. Lawrence and Thousand Islands)	10	0	10	6	14-185	1,000-3,200
Inside AOC	3	0	3	1	NA	0-17
Downstream of AOC (Lake St. Francis)	6	6	0	6	0.6-19	400-2,000

Table 6. Habitat characteristics of each osprey nesting site inside and outside the AOC.

N	Site	Inside or Outside AOC?	Local Area	Island Area (acres)	Artificial or Natural Site	Distance to Mainland
1	Picton Island	Upstream	Thousand Islands	185	Artificial	2,800
2	Little Round Island	Upstream	Thousand Islands	14	Artificial	800
3	Murray Island South	Upstream	Thousand Islands	120	Artificial	1,800
4	Murray Island North	Upstream	Thousand Islands	120	Artificial	3,200
5	Buoy 128	Upstream	Thousand Islands	Buoy	Artificial	1,000
6	Ogdensburg platform	Upstream	Lake St. Lawrence	Buoy	Artificial	1,000
7	Iroquois Dam	Upstream	Lake St. Lawrence	Pole	Artificial	0
8	Whitehouse Bay Pt	Upstream	Lake St. Lawrence	Pole	Artificial	0
9	Tiernan Rd.	Upstream	Lake St. Lawrence	Pole	Artificial	0
10	Wilson Hill	Upstream	Lake St. Lawrence	Pole	Artificial	0
11	S-curves	Inside	Lake St. Lawrence	Pole	Artificial	0
12	Massena Intake	Inside	Lake St. Lawrence	Pole	Artificial	0
13	Navigation cell 10	Inside	Raquette Point	Buoy	Artificial	17
14	Dickerson Island W	Downstream	Snye Marsh	9	Natural tree	1,200
15	Dickerson Island E	Downstream	Snye Marsh	9	Natural tree	1,200
16	Snye Marsh 147	Downstream	Snye Marsh	0	Natural tree	850
17	Snye Marsh 473	Downstream	Snye Marsh	19	Natural tree	680
18	Snye Marsh 139	Downstream	Snye Marsh	0	Natural tree	400
19	Cat Island	Downstream	Snye Marsh	0.6	Natural tree	2,000

Notes:
- Buoy indicates a navigation cell structure, pole, or buoy in the St. Lawrence River
- Pole indicates a nest platform mounted on a telephone pole or power pole on the mainland
- All structures on islands in the Thousand Islands are on power poles or platforms on poles

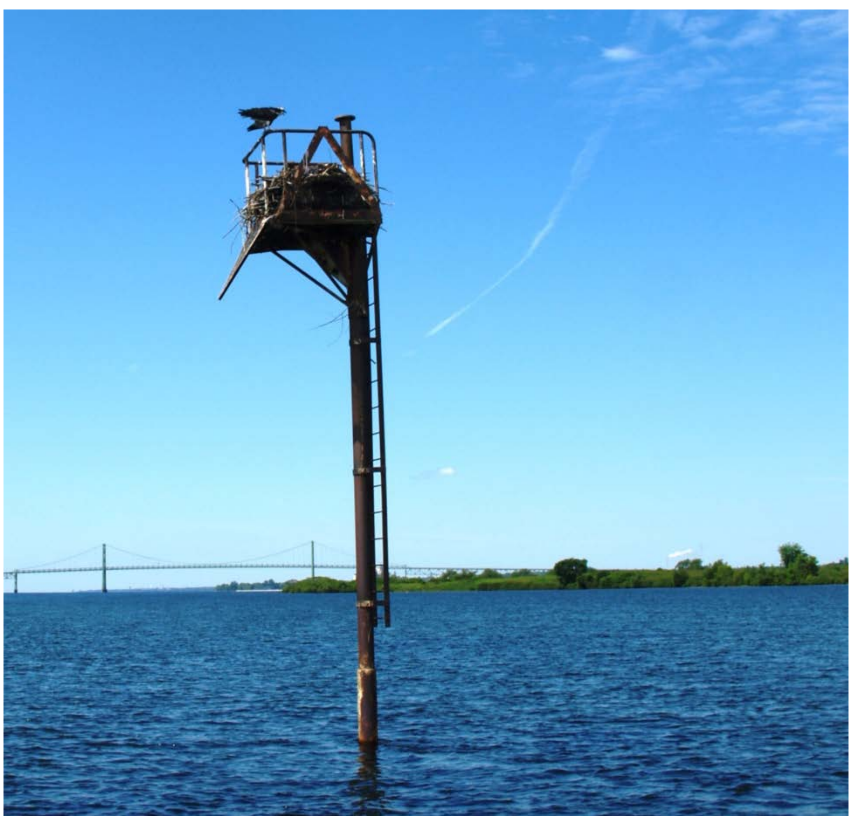

Photo 2. Most osprey nests upstream of the AOC are on artificial structures.

Herring Gull: Herring gulls nest at four sites near the AOC: Strachan Island and Bergin Rocks upstream of the Moses-Saunders Power Dam and immediately adjacent to the AOC off Barnhart Island (Photo 3), and two man-made islands with navigation structures near the eastern edge of Mohawk Territory at Akwesasne, D50 and D41. Each of these islands are inhabited by other colonial waterbirds, including ring-billed gulls (*Larus delawarensis*) and double crested cormorants (*Phalacrocorax auritus*).

These four nesting sites are small sandy or rocky islands that are located far from the mainland. Each island ranged in size from 0.17 acres (7,500 square feet) to 2.0 acres (87,200 square feet) and were anywhere from 965 to 2,575 meters (0.6 miles to 1.6 miles) from the mainland (Table 7). These islands contained large areas of stinging nettles, along with Virginia creeper, deadly nightshade (*Solanum dulcamara*), and reed canary grass (*Phalaris arundinacea*). The only trees on the islands are willows, which may contain nests of double-crested cormorants. Of these four nesting islands, both Strachan and Bergin Rocks are considered inside the AOC because herring gulls that nest on these islands forage inside the AOC. Bergin Rocks is a 2.0 acre island covered in sand and an assortment of small herbaceous plants with a single willow tree. The island is home to 17 pairs of herring gulls, over 80 pairs of cormorants and two pairs of great black-backed gulls (*Larus marinus*), as well as Canada goose (*Branta canadensis*), and mallard ducks (*Anas platyrhynchos*). Outside the AOC the gull colonies consisted of smaller, rockier islands with much less vegetation. Two are man-made islands with an armor stone perimeter with navigation markers on Lake St. Francis (D50 and D41). D50 is dominated by nesting ring-billed gulls. D41 has nesting herring gulls, black-backed gulls, and double-crested cormorants. The one colony upstream of the AOC, West Crossover Island just upstream of Oak Point, is a natural island of exposed bedrock.

Although herring gulls do not nest within the boundaries of the AOC, they are considered a sentinel species for the AOC because they forage inside the AOC. There are no small islands inside the AOC on the St. Lawrence River or the tributary rivers that are used for nesting by herring gulls (Harper and Jock 2014).

Table 7. Summary of habitat characteristics of herring gull nesting sites.

Location	Site	Island Area (acres)	Distance to Mainland (m)	Natural or Artificial
Upstream of AOC (Thousand Islands)	West Crossover	2.0	1,400	Natural
Inside AOC	Bergin Rocks	0.33	2,500	Natural
Downstream of AOC (Lake St. Francis)	D41	0.17	1,000	Artificial

Photo 3. Herring gulls nest with ring-billed gulls at Strachan Island.

Common tern: Common tern nesting sites on Lake St. Lawrence in the AOC and upstream of the AOC on Lake St. Lawrence are exclusively on man-made structures including navigation cells of the St. Lawrence Seaway (Photo 4). Although natural island sites were used by terns for nesting in the late 1990s and early 2000s, they have not been active in recent years. Upstream of Lake St. Lawrence, in the Thousand Islands region, there are two natural islands where terns occasionally nest. Both are owned by the Thousand Islands Land Trust (TILT). TILT and Save the River (STR) actively monitor and manage these colonies in an effort to establish successful nesting and restore common terns to the Thousand Islands region. On Lake St. Francis, there are no navigation cell structures that are used by common terns. The physical structure and construction of navigation cells on Lake St. Francis is different than those on Lake St. Lawrence. The smaller Lake St. Francis navigation structures do not have soil or stone on them for nesting, and the larger navigation islands with lighthouses are completely occupied by gulls and cormorants (*e.g.* D41 and D50). At one time, common terns nested on D50 (Harper and Jock 2014), although they did not nest there in 2013 nor in 2014.

Common tern nesting habitat inside and outside (upstream) of the AOC was confined to artificial sites such as navigation cells, mooring cells, and ice boom cells located inside and upstream of the AOC (Table 8). No similar structures exist inside the AOC downstream of the Moses-Saunders Power Dam. Although common terns have been known to nest at Christatie Island in Snye Marsh and at navigation island D50 (Harper and Jock 2014), neither of these sites were active in 2013 or in 2014.

The artificial sites where common terns nested in 2013 and 2014 are circular pillars of steel sheet piling with soil, cement, or pea gravel in the middle (Table 9). Most serve as navigation aids for the St. Lawrence Seaway and they are typically located a considerable distance from the mainland shoreline (450-1,100 meters or 0.3 to 0.7 miles). They serve as small, isolated islands and have sparse to no vegetation. The nest site characteristics of the four structures at one site known as Eisenhower Mooring Cells inside the AOC was very similar to the 12 sites outside (and upstream) of the AOC. Most nesting sites were small, only 420 to 580 ft², although some the smallest was only 250 ft² (the smallest of the Eisenhower Mooring Cells) and the largest was approximately 767 ft² at the larger ice boom cells (Table 8, Table 9).

The common tern is the subject of a habitat improvement project (HIP) being conducted by the New York Power Authority (NYPA). The Common Tern Habitat Improvement Project (HIP) started in

2005, and has enhanced nesting habitat for terns at all Lake St. Lawrence tern nesting sites. Additional enhancements have been made upstream of Ogdensburg in the Thousand Islands with support from NYSDEC and not-for-profit groups such as Save the River and the Thousand Islands Land Trust. On Lake St. Lawrence, the goal of the Common Tern HIP is to increase the number of nesting pairs to 1,400. When the project began, there were less than 500 nests on Lake St. Lawrence (Riveredge Associates 2014). In 2014, the three-year running average number of nests on Lake St. Lawrence was 822 (Riveredge Associates, in preparation). This project has increased the number of tern nests inside and upstream of the AOC on Lake St. Lawrence primarily by adding nesting gravel to artificial structures such as navigation cells to increase available high quality nesting habitat. There were no common tern nesting colonies downstream of the AOC on Lake St. Francis in 2013 or 2014; the closest downstream tern nesting colonies are located in and near Montreal.

Table 8. Summary of habitat characteristics of common tern nesting sites inside and outside the AOC.

Location	Sites	Number of Sites	Number of Artificial Sites	Number of Natural Sites	Island Area (ft^2)	Distance to Mainland (meters)
Upstream of AOC (Lake St. Lawrence)	Various navigation cells associated with St. Lawrence Seaway	12	12	0	420-767	1,400
Inside AOC	Eisenhower Mooring Cells (EMC)	1	1	0	1,025	500
Downstream of AOC (Lake St. Francis)	None	0	0	0	-	-

Table 9. Habitat characteristics of each common tern nesting site.

N	Site	Inside or Outside the AOC?	Local Area	Nesting Site area (ft^2)	Distance to Mainland (meters)	Natural or Artificial
1	Eisenhower mooring cells	Inside	Lake St. Lawrence	1025	500	Artificial
2	Navigation cell 51	Outside	Lake St. Lawrence	486	530	Artificial
3	Wilson Hill range light	Outside	Lake St. Lawrence	458	450	Artificial
4	Navigation cell 57	Outside	Lake St. Lawrence	420	880	Artificial
5	Navigation cell 58	Outside	Lake St. Lawrence	433	1,500	Artificial
6	Cat Island steering light	Outside	Lake St. Lawrence	563	980	Artificial
7	Navigation cell 73	Outside	Lake St. Lawrence	579	1,000	Artificial
8	Navigation cell 75	Outside	Lake St. Lawrence	477	1,100	Artificial
9	Navigation cell 79	Outside	Lake St. Lawrence	478	920	Artificial
10	Navigation cell 85	Outside	Lake St. Lawrence	460	1,100	Artificial
11	Ogden Island range light	Outside	Lake St. Lawrence	480	500	Artificial
12	Ice boom cell C	Outside	Lake St. Lawrence	767	1,000	Artificial
13	Ice boom cell B	Outside	Lake St. Lawrence	767	600	Artificial

Photo 4. Common terns nest on navigation cells of the St. Lawrence Seaway. This site is EMC inside the AOC. All tern sites are actively managed.

Black Tern: Black terns were monitored in this study because of their exceptional rarity on eastern Lake Ontario and the St. Lawrence River and the presence of a large breeding population in the Snye Marsh area. Black tern nesting habitat consisted of shallow, marshy areas of emergent wetland vegetation that ranged in size from 0.2 acres to large wetland complexes of 135 acres (Table 10). The nests in these wetland areas were located 50 meters (165 feet) to 1,000 meters (0.6 miles) from the mainland. There were no black tern colonies upstream of the AOC. All black tern colonies found during this study are downstream of the AOC. Historical records for black terns are known for Wilson Hill Wildlife Management Area (WHWMA) upstream of the AOC from the mid-late 1970s (Harper 1995, Harper *et al.* 1996). The restoration of black terns to those wetlands could be a potential future habitat improvement project. One goal of water level management in WHWMA is to promote hemi-marsh, a 50:50 mix of open water and wetland vegetation, a habitat type that is preferred by black terns (Heath *et al*. 2009).

In Snye Marsh, black tern nests were located in the vicinity of dense (95-98% cover) stands of tall, emergent vegetation, often rimmed with floating vegetation, amongst the open waters of the quieter, braided channels away from the main river channel. The dominant emergent vegetation at the nest sites consisted of either cattails (*Typha* sp.), hard-stemmed bulrush (*Schoenoplectus acutus*), or, less commonly, large bur-reed (*Sparganium eurycarpum*), sweet flag (*Acorus americana*), or common reed (*Phragmites australis*) (Table 11). Average height of the emergent vegetation was approximately 1.2-1.4 meters above water level. The emergent stands were often bordered by waist deep water densely to moderately covered with white water lily (*Nymphaea odorata*). The submerged vegetation varied from sparse to very dense, with milfoil (*Myriophyllum spicatum*) and water weed (*Elodea canadensis*) the dominant species. The vegetation in the vicinity of some of the nest sites was more varied, although always nearby was a dense stand of taller and denser emergent vegetation. All of the black tern nesting sites were located in these areas of emergent wetland vegetation (Photo 5). Black terns use the cut stems and wrack to build their floating nests (Photo 5).

Table 10. Summary of habitat characteristics of black tern nesting sites inside and outside the AOC.

Location	Sites	Number of Sites	Wetland Nesting Area (acres)	Distance to Mainland (meters)
Upstream of AOC (Lake St. Lawrence)	None	0	-	-
Inside AOC	None	0	-	-
Downstream of AOC (Snye Marsh on Lake St. Francis)	None	10-16	0.2 - 135	50 - 1,000

Photo 5. Black tern nesting habitat in Snye Marsh (above) and an adult incubating eggs in a floating nest (below).

Table 11. Plant species recorded at black tern nesting sites.

Scientific Name	Common Name
Acorus americana	Sweet flag
Alisma gramineum	Grass leaved water plantain
Alnus incana ssp. *rμgosa*	Speckled alder
Asclepias incarnata	Swamp milkweed
Bolboschoenus fluviatilis	River bulrush
Butomus umbellatus	Flowering rush
Carex comosa	Bristly sedge
Carex lasiocarpa	Wooly fruit sedge
Carex stricta	Tussock sedge
Elodea canadensis	Waterweed
Eupatorium perfoliatum	Boneset
Lythrum salicaria	Purple loosestrife
Myriophyllum spicatum	Eurasian milfoil
Nymphaea odorata	White water lily
Phalaris arundinacea	Reed canary grass
Phragmites australis	Common reed
Pontederia cordata	Pickerelweed
Potamogeton crispus	Curly pondweed
Potamogeton perfoliatus	Clasping leaved pondweed
Rumex verticillatus	Water dock
Salix x *fragilis*	Hybrid crack willow
Schoenoplectus acutus	Hard-stemmed bulrush
Sium suave	Water parsnip
Sparganium eurycarpum	Large bur-reed
Typha cf. x *glauca*	Cattail
Vallisneria americana	Tape-grass
Verbena hastata	Blue vervain

3.4 Reproduction and Productivity

Osprey, herring gull, common tern, and black tern nests were monitored for productivity inside and outside the AOC (Figure 4). In addition, data on bald eagle nest productivity were provided by the authors as well as by NYSDEC and by SRMTED.

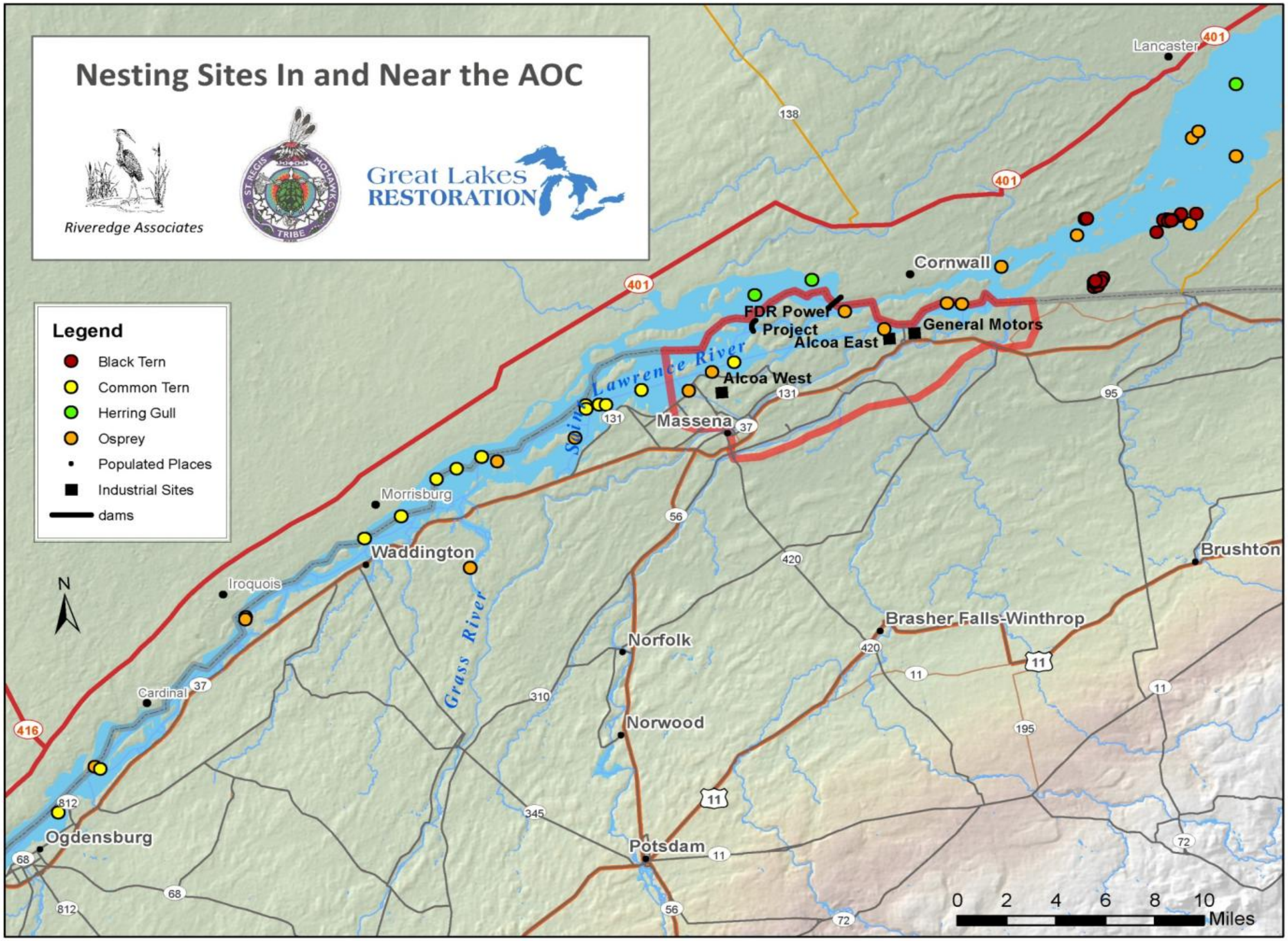

Figure 4. Avian nest sites monitored for productivity.

Osprey: Overall average productivity of osprey nests monitored during 2014 (n=19) was 1.6 chicks fledged per nest (Table 12). Average productivity inside the AOC for all nests was 1.3 chicks fledged per nest, including all nests from which one egg was removed for contaminant analysis (4 chicks/3 nests). Outside and upstream of the AOC, average productivity for all osprey nests was 1.7 chicks per nest for all nests (17 chicks/10 nests). Productivity outside and downstream of the AOC was lowered by a single nest in Snye Marsh that contained three young chicks on the first nest check but was found to contain no chicks at all one week later (Nest 18, Table 13), but was still 1.5 chicks fledged per nest (Table 12). This particular nest was low to the water and could have been depredated by a mammalian or avian predator (Photo 6). In 2013, the osprey nests on platforms of the NYPA HIP on Lake St. Lawrence fledged 13 chicks from 7 nests on platforms or 1.9 chicks per nest (Michael Morgan, personal communication). In 2013 inside the AOC, only two nests were found, and these nests fledged 1.5 chicks per nest. A third nest was partially built at a new site by a new nesting pair but no eggs were laid. Of the chicks observed at close range in nests in 2014 (n=9), none had visible deformities.

Table 12. Summary of osprey productivity inside and outside the AOC in 2014.

Location	Number of Nests	Number of Chicks Fledged	Average Number of Chicks Fledged per Nest
Upstream of AOC (Lake St. Lawrence and Thousand Islands)	10 [1]	17	1.7
Inside AOC	3 [2]	4	1.3
Downstream of AOC (Lake St. Francis)	6	9	1.5
Overall average productivity	19	30	1.6

[1] Two of these 10 nests had one osprey egg removed for contaminant analysis
[2] Each of the three nests inside the AOC had one egg removed for contaminant analysis

Table 13. Productivity of each osprey nest in 2014. Osprey nests sorted by longitude (west to east)

N	Site	Inside or Outside AOC?	Local Area	Chicks	Nests	Productivity
1	Picton Island	Upstream	Thousand Islands	2	1	2
2	Little Round Island	Upstream	Thousand Islands	2	1	2
3	Murray Island South	Upstream	Thousand Islands	2	1	2
4	Murray Island North	Upstream	Thousand Islands	2	1	2
5	Buoy 128	Upstream	Thousand Islands	1	1	1
6	Ogdensburg platform	Upstream	Lake St. Lawrence	1	1	1
7	Iroquois Dam	Upstream	Lake St. Lawrence	2	1	2
8	Whitehouse Bay Pt [1]	Upstream	Lake St. Lawrence	1	1	1
9	Tiernan Rd. [1]	Upstream	Lake St. Lawrence	2	1	2
10	Wilson Hill	Upstream	Lake St. Lawrence	2	1	2
11	S-curves [1]	Inside	Lake St. Lawrence	2	1	2
12	Massena Intake [1]	Inside	Lake St. Lawrence	1	1	1
13	Navigation cell 10 [1]	Inside	Raquette Point	1	1	1
14	Dickerson Island W	Downstream	Snye Marsh	1	1	1
15	Dickerson Island E	Downstream	Snye Marsh	2	1	2
16	Snye Marsh 147	Downstream	Snye Marsh	3	1	3
17	Snye Marsh 473	Downstream	Snye Marsh	1	1	1
18	Snye Marsh 139	Downstream	Snye Marsh	0	1	0
19	Cat Island	Downstream	Snye Marsh	2	1	2
Total Average Productivity (all nests)				30	19	1.6

[1] These sites had one osprey egg removed for contaminant analysis
[2] Each of the three nests inside the AOC had one egg removed for contaminant analysis

Photo 6. Osprey nests on tree stumps in Snye Marsh. Note three osprey chicks in nest in lower photo.

Herring Gull: In 2014, productivity for herring gull was calculated for gulls nesting at West Crossover Island, Bergin Rocks, and island D41. Average productivity at Bergin Rocks was 1.7 chicks fledged per nest (29 chicks/17 nests) (Table 14). Average productivity was lower at West Crossover Island (Photo 7) at 1.0 chicks per nest (14 chicks/14 nests) and at D41 at 0.9 chicks per nest (22 chicks/25 nests) (Table 14). Of the herring gull chicks observed (n=63), none had visible deformities.

In 2013, site D41 fledged seven chicks from three nests or 2.3 chicks per nest. In contrast, Bergin Rocks only fledged two chicks from 48 nests in 2013 or 0.04 chicks per nest (Doug Crump, CWS, personal communication). These nests were being closely monitored by CWS and a predator such as great horned owl or peregrine falcon decapitated the gull chicks at this site. These data are indicative of the variability in productivity from year to year in colonial waterbirds.

Table 14. Productivity of herring gull in 2013 and 2014.

Location	Site	Chicks	Nests	Productivity
2014				
Upstream of AOC (Thousand Islands)	West Crossover	14	14	1.0
Inside AOC	Bergin Rocks	29	17	1.7
Downstream of AOC (Lake St. Francis)	D41	22	25	0.9
Total Average Productivity (2014)		63	69	0.9
2013				
Inside AOC	Bergin Rocks	2	48	0.04
Downstream of AOC (Lake St. Francis)	D41	7	3	2.3
Total Average Productivity (2013)		9	51	0.2

Photo 7. Herring gull nests at West Crossover Island.

Common Tern: Productivity for common tern inside the AOC in 2014 was calculated from the four cells of the Eisenhower mooring cell site. These four cells had an average productivity of 1.6 chicks per nest (Table 15), almost as high as any of the 13 total sites (Table 16) despite collecting 30 eggs for contaminant analysis from this site. Productivity for common terns outside and upstream of the AOC was calculated from a twelve common tern colonies between Massena NY and Ogdensburg NY. These twelve sites had an average productivity of 1.4 chicks per nest (Table 16). These average productivity values are very similar for common terns nesting inside and outside the AOC. Productivity of common terns at these sites was much lower in 2013 when almost every tern nesting site was hit by great horned owls and peregrine falcons (Riveredge Associates 2014). In 2013, productivity across all these sites was only 0.7 chicks fledged per nest.

In 2014, a total of 1,268 common tern chicks was banded on Lake St. Lawrence, including 288 chicks inside the AOC at the Eisenhower Mooring Cells. None of these chicks had visible deformities. Over the last 25 years, Harper has banded 1,089 tern chicks inside the AOC and 15,228 tern chicks within 25 miles of the AOC on Lake St. Lawrence. Of the total 16,317 tern chicks banded, three have been found with crossed-bill deformities (Photo 8), two outside the AOC and one inside the AOC. Overall, this is a rate of 0.02%. Deformities were also found in common tern chicks hatched on the St. Lawrence River by Karwowski (1992). Karwowski (1992) observed two types of chick deformities between 1986 and 1990. In 1986 and 1987, the abnormalities observed were of curved mandibles. In 1990 deformities of the toes were observed. The percent prevalence of chick deformities in 1986, 1987, and 1990 were 0.40, 0.25, and 0.22 respectively (Karwowski, 1992), higher than has been observed in the AOC or within 25 miles of the AOC since 1990 in chicks handled for banding. Hughes *et al.* (2014) examined common tern chicks in the St. Mary's River AOC and found no deformities in 2011 and 2012. However, embryos that were artificially incubated had deformity rates of 0% to 8% in 2011 and 2012, including crossed-bills.

Table 15. Summary of common tern productivity in 2014.

Location	Sites	Chicks	Nests	Productivity
Upstream of AOC (Thousand Islands)	12 artificial sites from AOC to Ogdensburg	973	706	1.4
Inside AOC	Eisenhower Mooring Cells (EMC)	353	221	1.6
Downstream of AOC (Lake St. Francis)	None	-	-	-
Total Average Productivity		1,326	927	1.4

Table 16. Productivity of common tern at each nesting site in 2014.

N	Site	Inside or Outside the AOC?	Chicks	Nests	Productivity
1	Eisenhower mooring cells	Inside	353	221	1.6
2	Navigation cell 51	Outside	0	16	0.0
3	Wilson Hill range light	Outside	92	51	1.8
4	Navigation cell 57	Outside	58	45	1.4
5	Navigation cell 58	Outside	81	68	1.3
6	Cat Island steering light	Outside	96	70	1.3
7	Navigation cell 73	Outside	78	54	1.4
8	Navigation cell 75	Outside	74	54	1.4
9	Navigation cell 79	Outside	89	68	1.3
10	Navigation cell 85	Outside	86	55	1.6
11	Ogden Island range light	Outside	43	18	2.5
12	Ice boom cell C	Outside	156	100	1.5
13	Ice boom cell B	Outside	120	107	1.2
Overall average productivity			1,326	927	1.4

Photo 8. Common tern adult (left) and a chick with a crossed-bill deformity (right) from Eisenhower Mooring Cells (EMC).

Black Tern: Productivity is difficult to calculate for black terns because the chicks are capable of leaving the nest when approached soon after hatching and empty nests do not necessarily indicate nest failure. The chicks are well camouflaged and hide in the marsh, and return to the nest when the adults return (Photo 9). In 2013, 74 black tern nests were located at 16 wetland sites in Snye Marsh with an average of 2.2 eggs per nest. Because chicks scattered quickly from nests, a reliable estimate of the number of chicks fledged in 2013 could not be determined. In 2014, 78 black tern nests were located in ten areas of Snye Marsh (Table 17). Each nesting area contained from two to 28 nests. Across all 78 black tern nests, 40 chicks were confirmed to be present by direct observation. This indicates an overall average productivity of 0.5 chicks per nest. However, some of these nests likely had chicks that could not be found without undue disturbance to the nesting birds. If productivity for black terns was calculated only from nests where chicks were actually observed by direct observation or by detection with monitoring cameras, the average productivity was determined to be 40 chicks from 20 nests or 2.0 chicks per nest. At many of the nests that appeared to be empty, the adults vigorously defended the nest site suggesting chicks were, in fact, present. If half of the remaining 58 nests had two chicks each (29 nests with 58 chicks), the average productivity of all 78 nests would be 1.3 chicks per nest (98 chicks from 78 nests). Fledging rates were roughly estimated from the number of juvenile black terns seen flying over the marsh later in the year as compared to the known number of nests in an area, but this measure is crude at best. Nonetheless, these observations indicated approximately one fledged chick per nest which is still excellent productivity and indicative of a stable population. Unpublished field notes of Harper from 1999 suggested about 65 black tern nests in the area, although the nest searches conducted then were not as extensive as those conducted in 2014. These observations suggest that the black terns nesting in Snye Marsh are doing well and likely more stable than in other areas of the St. Lawrence River and eastern Lake Ontario where numbers are lower (Irene Mazzocchi, NYSDEC black tern coordinator, personal communication). Combined in 2013 and 2014, a total of 54 black tern chicks were examined for evidence of deformities (Photo 10). No deformities were found in black tern chicks in Snye Marsh.

Because black terns are both rare and also sensitive to disturbance, the locations of black tern nests in the Snye Marsh of Akwesasne have not been mapped in detail in this report. GPS locations of known nests and nesting areas and the productivity of each area are on file with SRMTED.

Table 17. Summary of black tern productivity in 2014.

Location	Sites	Chicks	Nests	Productivity
Upstream of AOC (Thousand Islands)	None	-	-	-
Inside AOC	None	-	-	-
Downstream of AOC (Lake St. Francis)	Snye Marsh	40	78	0.5 [1]

[1] 40 chicks were observed in 20 nests. Actual productivity probably higher. See text for details.

Photo 9. Black tern chicks are highly mobile after hatching and well camouflaged in the wetland. Three chicks are visible in this picture.

Photo 10. Black tern chicks and fledglings in Snye Marsh. Note wetland nesting habitat in background of lower photo.

Bald Eagle: Bald eagles are known to nest in the area and two nests are located inside the AOC. Two more nests are located upstream of the AOC. Of the two nests inside the AOC, one is upstream of Moses-Saunders Power Dam. The other is downstream of the dam in the vicinity of Raquette Point. Upstream of the AOC, bald eagles nest at two sites: one near WHWMA in Louisville and another near Sucker Brook in Waddington. In 2014, three chicks were produced from two nests both inside and outside the AOC (Table 18) for an average productivity of 1.5 chicks fledged per nest. The nests upstream of the AOC fledged the same number of chicks in both 2013 and 2014 (one chick at Sucker Brook and two chicks at WHWMA in each year). The average productivity at the two nests inside the AOC was 1.5 in 2014 and also 1.5 in 2013. Each nests fledged 3 chicks over the two years (1 chick in one year and two chicks in the other year). The fact that these nests successfully fledged chicks in both years suggests the absence of reproductive issues in and near the AOC. Because bald eagles are a threatened species in New York and sensitive to disturbance, nest locations are not described in detail nor mapped in this report.

Table 18. Summary of bald eagle productivity in 2014.

Location	Sites	Chicks	Nests	Productivity
Outside and Upstream of AOC (Lake St. Lawrence)	Sucker Brook (Town of Waddington)	1	1	1
	WHWMA (Town of Louisville)	2	1	2
Inside AOC	Long Sault Island (Town of Massena)	1	1	1
	Raquette Point (Akwesasne)	2	1	2
Downstream of AOC (Lake St. Francis)	None	-	-	-
Total Average Productivity Outside the AOC		3	2	1.5
Total Average Productivity Inside the AOC		3	2	1.5

3.5 Contaminants

Eggs were collected in the field at selected locations (Figure 5) and transported to the lab for processing following the SOPs of the QAPP (Photo 11). Sample mass limitations prevented all analyses from being conducted on all samples. All 30 samples were analyzed for PCBs, pesticides, metals, and lipids. Twenty-nine of the 30 samples were analyzed for mercury. Eighteen of the samples were analyzed for fluoride. Dioxin and furan sampling required more mass and only four samples from inside the AOC were tested for dioxins and furans.

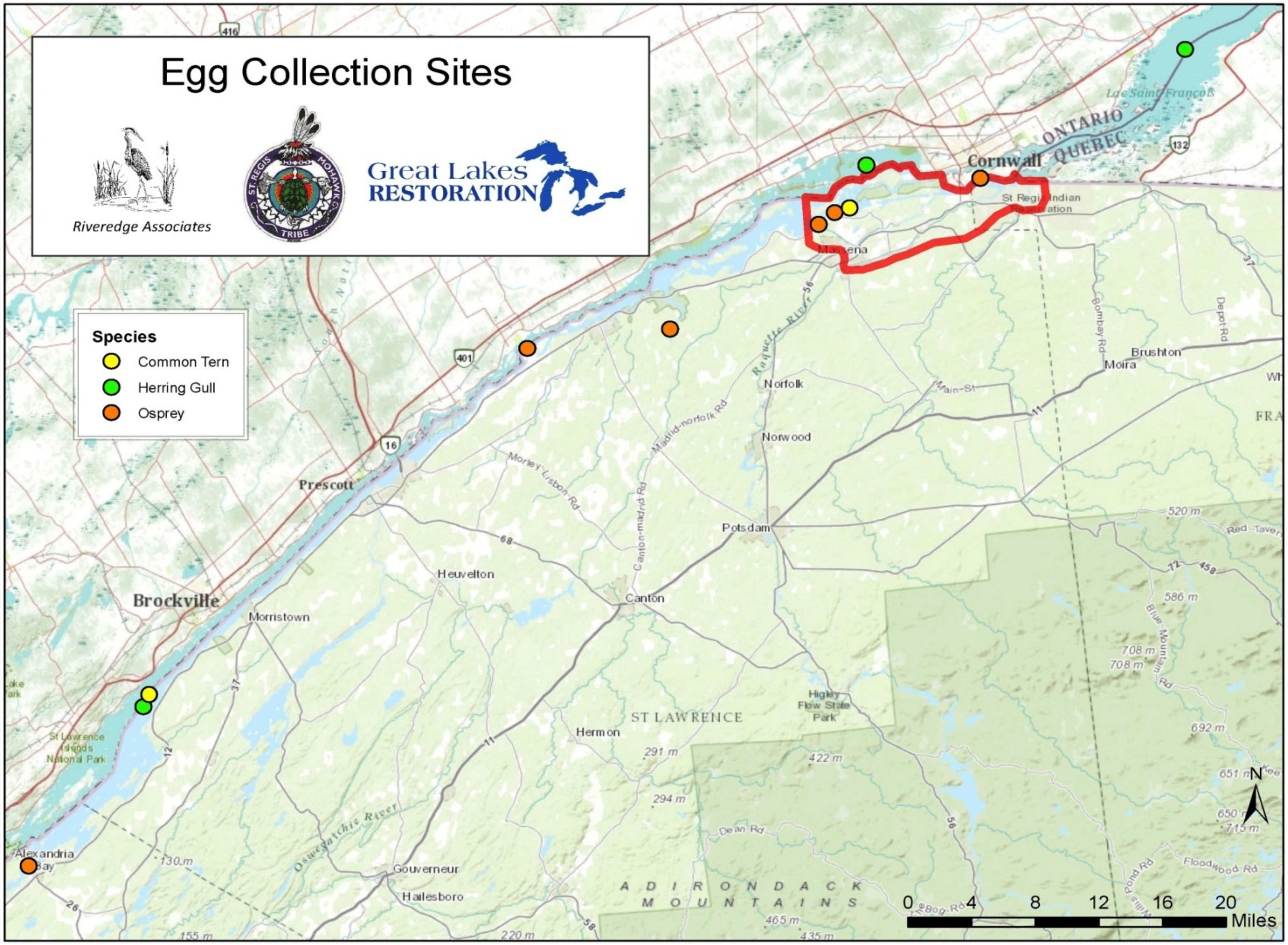

Figure 5. Egg collection sites for contaminant testing.

3.5.1 Quality Assurance and Quality Control

Osprey and herring gull eggs were collected over four days from May 2 to May 8, 2014. Eggs were processed, frozen and shipped overnight on ice to Pace Analytical Laboratories. Samples were received at Pace on May 14 intact and within holding times. Samples were extracted by Pace and analyzed. All quality assurance parameters were met for the analysis of congener specific PCBs, mercury, metals, dioxins/furans, fluoride, and lipids. Samples were extracted outside the required holding time for pesticides. Common tern samples were collected on May 23 and May 27, processed, frozen, shipped overnight on ice to Pace Analytical Laboratories. Pace received the samples at the laboratory on June 11 intact and within holding times. However, temperature of the samples was above the recommended temperature of 0-6 degrees C upon receipt at Pace Analytical. The measured temperature was 12.4 degrees C. In addition, samples were extracted and analyzed outside the required holding times for pesticides, PCBs, and lipids. For mercury, samples were extracted outside holding times and 19 of 30 samples were analyzed outside the required holding times. Samples were extracted as late as July 12 and analyzed as late as July 30. For pesticides, surrogate compound tetrachlorometaxylene was recovered above established quality control limits in three samples and below these limits in one sample. Surrogate compound decachlorobiphenyl was recovered above quality control limits in two samples. The alternate surrogate compound in each of the associated samples was recovered within the acceptable range. For the metals analysis lead was recovered above established quality control limits in the opening and closing Contract Required Detection Limit standard. Analytical bias is not indicated as lead was not detected in the associated samples. For PCB analysis the surrogate compound nonachlorobiphenyl was recovered above established quality control limits in one sample. The sample could not be reextracted and reanalyzed due to insufficient sample volume.

3.5.2 Data Treatment

Data were not normally distributed so we selected a non-parametric approach for statistical comparisons. Only one composite sample (13 eggs) of herring gull eggs was collected inside and outside the AOC and so we provide only the values of these samples for this species. For osprey and common terns, we used Wilcoxon tests to compare contaminant concentrations inside the

AOC and outside the AOC. In all cases, comparisons were made when $n \geq 3$. In all cases, results are reported in µg/g wet weight (ww) unless noted to facilitate comparisons with other studies. Dioxin and furan concentrations were not analyzed in osprey eggs because only single eggs were used and they do not provide sufficient sample mass for this analysis in addition to the other analyses performed.

3.5.3 Results

Contaminant values in ospreys, herring gulls, and common terns were variable (Table 19, Table 20, Table 21). Total PCBs were significantly higher in common tern eggs inside the AOC (0.96 ± 0.23 µg/g than outside the AOC (0.49 ± 0.058 µg/g) (Table 21). Although herring gull egg contaminant concentrations were not included in the statistical analysis, their range of total PCBs was higher (1.03 – 3.93 µg/g) than for either osprey or terns (Table 19, Table 20, Table 21). Importantly, for contaminants detected in both herring gull egg composites (see Table 20), the downstream egg composite from navigation structure D41 had the higher concentration (indicative of downstream transboundary impact) and the upstream composite sample collected from the Thousand Islands region was the less contaminated sample. Mean Hg was higher in osprey eggs collected inside (0.23 ± 0.10 µg/g) versus outside (0.09 ± 0.01 µg/g) the AOC (Table 19). Interestingly, hexachlorobenzene (HCB) in common tern eggs was significantly higher outside the AOC as compared to inside the AOC (0.004 ± 0.0004 µg/g, and 0.003 ± 0.0002 µg/g, respectively), but there was no difference for osprey (Table 19, Table 21).

There were no significant differences in DDE concentrations among the three species inside the AOC as compared to outside the AOC, although common terns had the lowest range of DDE concentrations while osprey and herring gull had similar ranges (Table 19, Table 20, Table 21). There were also no significant intra-species differences in the organochlorine heptachlor epoxide inside the AOC versus outside the AOC, but concentrations were lowest in terns, and similar between osprey and herring gull (Table 19, Table 20, Table 21). Lastly, the range of fluoride concentrations in osprey eggs outside (upstream) the AOC (17.0 - 23.0 µg/g; n = 3) was higher than the range of fluoride concentrations inside the AOC (n =3, 4.1 – 6.3), but the sample size inside the AOC (n=2; one was ND) was insufficient for statistical comparison (Table 19).

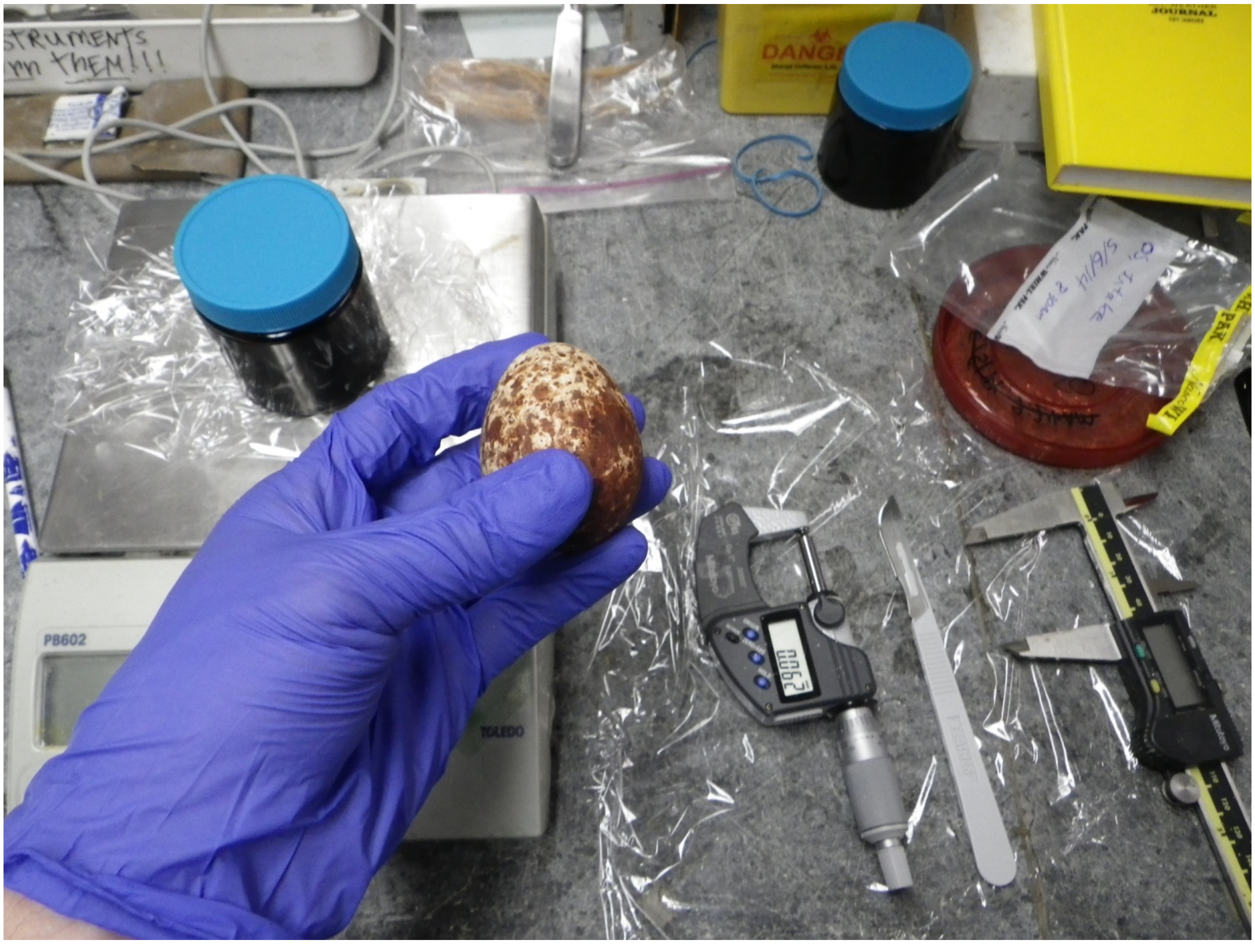

Photo 11. Eggs of sentinel species were collected for contaminant analysis. The thickness of eggshells were measured as well. This photo illustrates an osprey egg.

3.5.4 Comparison with Other Studies

Although the assessment area supports a high diversity and abundance of birds, data on contaminant concentrations in birds are limited (Natural Resource Trustees of the St. Lawrence River Environment 2013). Previous assessments of avian contaminant body burden of the AOC and environs included great blue heron (Champoux *et al.* 2002, 2006, 2010), tree swallow (Bishop *et al*. 1995,1999) and red-winged blackbird (Bishop *et al*. 1995). These studies found average PCB concentrations from Akwesasne ranging from 6.1 to 18.6 μg/g (Natural Resource Trustees of the St. Lawrence River Environment 2013). In some species, these levels could be high enough to exceed literature based adverse effects thresholds (Table 22, Table 23) (Natural Resource Trustees of the St. Lawrence River Environment 2013). Contaminant levels in eggs of osprey, herring gull and common tern collected inside and outside the AOC and the potential for adverse effects are discussed below by contaminant of concern. Adverse effects thresholds for dioxin-like compounds and PCB 126 are listed in Table 22, and for PCBs in Table 23.

PCBs

Hoffman *et al*. (1998) found adverse effects in common terns for PCB 126 at levels as low as 44 ng/g. Adverse effects included malformation, edema, reduced hatching success, and cross bill deformities (Table 22). In addition, Hoffman *et al.* (1998) determined the LD50 for PCB 126 to be 65 ppb. Hoffman *et al*. (1998) suggested that three PCB congeners (126, 77, 105) may account for over 90% of the PCB toxicity in eggs of birds in the Great Lakes, including a common tern relative, the Forster's tern. In this study, PCB 126 and 77 were not detected in any common tern sample. PCB 105 was detected in every sample with a range of values from 0.00777 to 0.138 and a mean of 0.025 ± 0.0043 μg/g (SE). This value is below the adverse effects threshold reported by Hoffman *et al*. (1998) for PCB 126.

In two laboratory studies, negative effects on parental behavior were observed in American kestrels and zebra finches when egg PCB concentrations ranged between 0.2 – 34.0 μg/g (Hoogesteijn *et al.* 2005, Fisher *et al.* 2006). Similarly, total PCB concentrations in wild Foster’s tern eggs of 5.1 – 29.5 μg/g were also associated with similar negative parental behavioral patterns (Kubiak *et al.* 1989). In common terns, embryolethality in eggs injected with PCB congener 126 occurred at concentrations between 44 – 104 µg/g (Hoffman *et al.* 1998). French *et al.* (2001) looked for evidence that PCBs alter blood hormone concentrations in common terns, but they found no relationship between total PCBs and steroid concentrations. In osprey, elevated stores of vitamin A in chicks were reported at egg PCB concentrations of 5.0 – 10.0 µg/g (Elliot *et al.* 2001) and herring gull chicks in the wild experienced altered vitamin A levels at maternal egg concentrations of 14 – 27 µg/g (Grasman *et al.* 1996). Osprey fledging rate was unaffected at egg PCB concentrations of 0.5 – 1.7 µg/g (Woodford *et al.* 1998). Kubiak *et al.* (1989) and Gilman *et al.* (1977) reported negative effects on reproduction in Forster's terns and herring gulls at egg PCB concentrations between 23 – 142 µg/g. Thus, based on the above laboratory and field studies, PCB concentrations in the current study (2014) are lower than concentrations thought to impact reproduction or population viability for most avian taxa (Table 22, Table 23). However, while concentrations appear to be low for target species in the current study, it is important to note that PCBs in higher trophic fish exceeded the protective wildlife criterion of 110 µg/g by nearly as much as an order of magnitude in fish (Newell *et al.*, 1987; Arcadis 2008; Alcoa 2001, 2012).

Osprey: Mean total PCBs in osprey eggs in the current study inside and outside the AOC ranged from 0.48 – 2.84 µg/g (Table 19). Between 1991 and 1995, Martin *et al.* (2003) analyzed total PCBs in osprey eggs collected throughout the Great Lakes Basin including the upper St. Lawrence River near Mallorytown (55 miles upstream of the AOC) and documented a mean total PCB concentration of 1.2-2.9 µg /g, but the highest mean reported was from Kawartha Lakes (7.1 µg/g). However, in all cases Martin *et al.* (2003) reported that reproductive output exceeded the threshold of 0.8 young produced per nest to maintain stable populations.

Herring Gull: Mean total PCBs in herring gulls in the present study outside the AOC range from 1.03 – 3.93 µg/g; slightly higher than osprey concentrations inside or outside the AOC, but lower than levels known to induce toxicity (Table 20) (see below and Table 23). At Strachan Island, located just upstream of the Moses-Saunders Power Dam and adjacent to the Massena/Akwesasne AOC, Weseloh *et al.* (2006) reported a mean total PCB concentration of 9.3 µg/g in herring gull eggs collected between 1998-2002 (n = 5; 1 sample per year, each of 13 egg composites). Importantly, the most recent data available (2013, on file with SRMT) for Strachan

Island herring gulls (S. De Solla, pers. comm.) report a total PCB egg concentration for n = 1 (13 egg composite) of 3.03 µg/g; which is within the range we report in the current study (Table 20). Braune and Norstrom (1989) analyzed PCBs in herring gull eggs collected from eastern Lake Ontario in 1985 and report a mean total PCB concentration of 16.0 ± 3.4 (SD) µg/g. Prior to that, Gilman *et al.* (1977) reported mean PCB concentration in herring gulls eggs (collected 1975) of 142 µg/g in Lake Ontario eggs, 65.8 µg/g in Lake Erie eggs, 51.5 µg/g in Lake Huron eggs, 60 µg/g in Lake Superior eggs, and 91.3 µg/g in Lake Michigan eggs. Gilman *et al.* (1977) further report highest egg failure from the Lake Ontario population, which exhibited the highest PCB concentrations. Conversely, Kannan *et al.* (2001) report much lower mean total PCB concentrations of 1.65 µg/g in herring gull eggs from Little Charity Island in Lake Huron and 4.1 µg/g in herring gull eggs from Taquamenon Island in Lake Superior, all of which were collected in 1998. On Corossol Island in the Gulf of St. Lawrence, Lavoie *et al.* (2010) report a mean total PCB concentration of 16.12 µg/g for herring gull eggs collected in 2007.

Common Tern: Karwowski (1992) evaluated contaminants in common tern eggs collected from the upper St. Lawrence River outside the AOC between 1986 and 1989 and reported a range of total PCBs of (n = 41) 1.90 – 9.60 µg/g, higher than the range we report inside the AOC (0.47 – 3.95 µg/g) and outside the AOC (0.24 – 1.05 µg/g) (Table 21). He concluded that common terns were a good indicator of local contamination, and found that levels of PCBs, DDE, dieldrin, and mercury may be related to low reproductive success of terns at some colonies and to the types and rates of abnormalities observed in chicks (Karwowski, 1992). Furthermore, Karwowski (1992) and Harper (unpublished data) have reported occasional bill and toe deformities for nesting common terns in the upper St. Lawrence River. Weseloh *et al.* (1989) collected tern eggs from an eastern Lake Ontario colony in 1981 and reported the range of total PCBs (n = 10) 6.56 – 17.36 µg/g. In the highly contaminated Detroit River AOC, Szczechowski (2007) reported that PCB concentrations in tern eggs remained unchanged between the sampling years 1991 (4.4 µg/g) and 2003 (4.45 µg/g). At a highly contaminated site in Lake Michigan, Ward *et al.* (2010) reported a mean total PCB concentration of (n=10, 10.96 ± 1.4 µg/g).

Mercury (Hg)

Methylmercury (MeHg) accounts for > 90% of total Hg in bird eggs (Bond and Diamond 2009) which is the form most toxic to wildlife (Eisler 1987). MeHg can have a range of sub-lethal and lethal effects on wildlife including altered behavior, reproductive impairment, and endocrine or immune system disruption (Burgess, 2005). In birds, acute responses to MeHg toxicity include reduced parental care of young, altered foraging behavior, developmental impairment, asymmetrical feather development, and increased vulnerability to parasites (Evers *et al.* 1998; Meyer *et al.* 1998; Evers *et al.* 2008). In regard to egg Hg concentrations, documented negative effects thresholds of 1.0 - 1.3 μg/g have resulted in embryo deformities, reduced hatchability, and/or impaired chick growth (Heinz and Hoffman 2003, Evers *et al.* 2003). Further, Fimreite (1974) documented reproductive failure in common terns breeding in Northwestern Ontario when egg Hg concentrations exceeded 3.65 μg g. In the current study, the overall range of egg Hg concentrations for all three species is 0.07 – 0.77 μg/g which appears to be below toxic effects thresholds described above.

Osprey: Mercury was significantly higher in osprey eggs collected inside (0.23 ± 0.10 μg/g, n = 3) versus outside (0.09 ± 0.01 μg/g, n = 3) the AOC (Table 19). Indeed, the highest Hg concentration outside the AOC (0.11 μg/g) was lower than the lowest Hg concentration inside the AOC (0.13 μg/g; Table 19).

Herring Gull: On Corossol Island in the Gulf of St. Lawrence, Lavoie *et al.* (2010) report similar Hg concentrations in herring gull eggs (0.43 μg/g) as in herring gulls in the current study outside the AOC (range = 0.33 – 0.52 μg/g; Table 20). In the Great Lakes, the Canadian Wildlife Service has been running the longest annual contaminant monitoring study in the world (Weseloh *et al.* 2011). Weseloh *et al.* (2011)) and Hughes *et al.* (2010) report recent (2009) Hg concentrations in herring gull eggs ranging from 0.064 μg/g at Chantry Island (Lake Huron) to 0.246 μg/g on Middle Island (Lake Erie); slightly lower than the highest Hg concentrations reported in the current study for herring gulls and osprey (Table 19, Table 20). Overall, Weseloh *et al.* (2011)) and Hughes *et al.* (2010) report that herring gull egg Hg concentrations declined at 10 of 15 Great Lakes sites between 1973 and 2009 (highest mean Hg concentration = 0.52 μg/g in 1982 at Agawa Rocks, Lake Superior), but that Channel-Shelter Island (Lake Huron), Strachan Island (St. Lawrence River), and Gull Island (Lake Michigan) were the three most contaminated sites when all contaminants analyzed were included in the ranking. Importantly, the most recent data (2013, on file with SRMT) from Strachan Island (S. De Solla pers. comm.) report herring gull Hg concentration (one 13 egg composite) of 0.881 μg/g dry weight, while Hughes *et al.*, (2010) report that Hg concentrations in herring gull eggs from Strachan Island from 2003 to 2007 did not approach the threshold level of 0.5 μg/g typically associated with adverse reproductive effects in birds (range=0.16 to 0.25 μg/g; Thompson 1996).

Common Tern: Although there was no significant difference between Hg concentrations in common tern eggs collected inside the AOC (n = 15) as compared to outside the AOC (n = 14) (Table 21), the two egg samples with the highest concentrations (0.65 and 0.774 μg/g) were collected outside the AOC.

DDE

Eggshell thinning due to DDT and its metabolites has been shown to have negative impacts on reproductive productivity for multiple avian taxa. Anderson and Hickey (1972) estimated that a reduction in eggshell thickness of 15-20% may be associated with avian population declines. Eggshell thickness in osprey prior to DDT exposure has been reported to be 0.505 mm (Anderson and Hickey, 1972). Estimates of DDE concentrations associated with 20% eggshell thinning are generally above 5 μg/g (Kiff *et al.* 1979), and Wiemayer *et al.* (1975) reported a minimum of 8.0 μg/g DDE in which osprey exhibited 15% mean eggshell thinning. Similarly, Blues (2011) estimated a minimum of 18% eggshell thinning as a minimum effects level associated with negative population and/or reproductive impacts.

In terms of reproductive success, Weseloh *et al.* (1983) showed residues as low as 5.0 μg/g in double crested cormorants resulted in only 0.3 young produced per nest; well below the minimum threshold of 0.8 to maintain a stable population. In osprey, Johnson *et al.* (1975) reported 1.6 young produced per nest at 6.0 μg/g in eggs and Spitzer *et al.* (1978) reported 0.0 young produced per nest at 23.0 μg/g DDE concentration in eggs. Importantly, Garcelon and Thomas (1997) calculated a toxicity threshold of 8.0 μg/g in bald eagle (*Haliaeetus* *leucocephalus*) eggs where reproductive impairment occurs. DDE concentrations reported in the current study (0.12 – 1.01 µg/g), are below concentrations thought to induce reproductive and/or population declines.

Osprey: DDE concentrations in osprey eggs were similar inside the AOC (0.44 ± 0.29 µg/g) and outside the AOC (0.16 ± 0.02 µg/g) with the exception of one sample from inside the AOC that had a concentration of 1.01 µg/g (Table 19). In osprey eggs collected throughout the Great Lakes Basin between 1991 – 1995, Martin *et al.* (2003) report a range of DDE concentrations between 0.256 – 8.64 µg/g.

Herring Gull: Concentrations of DDE in the two herring gull egg samples collected were 0.24 and 0.50 µg/g outside the AOC (Table 20). Gilman *et al.* (1977) analyzed DDE in herring gull eggs collected across the Great Lakes in 1974-75 and report mean concentrations of 22.6 µg/g (Lake Ontario), 7.04 µg/g (Lake Erie), 13.8 µg/g (Lake Huron), 18.6 µg/g (Lake Superior), and 31.8 µg/g (Lake Michigan). In 1985, Braune and Norstrom (1989) analyzed herring gull eggs from Snake Island, Lake Ontario and report a mean DDE concentration of 5.4 µg/g. At Strachan Island adjacent to the Massena/Akwesasne AOC, Weseloh *et al.* (2006) report a mean herring gull egg DDE concentration of 1.82 µg/g for samples collected between 1998 – 2002. However, the most recent Strachan Island data from 2013 (S. De Solla pers. comm.) report a DDE concentration (n = 1; 13 egg composite) of 0.646 µg/g, consistent with our results in the current study (Table 20). On Corossol Island in the Gulf of St. Lawrence, Lavoie *et al.* (2010) report mean DDE concentrations in herring gull eggs of 2.69 µg/g, all of which are higher than reported in the current study (Table 20). Overall, DDE concentrations in herring gulls in the current study are lower than concentrations reported in Lake Ontario, Strachan Island, and elsewhere, but a more robust sampling scheme is needed for verification.

Common Tern: The mean and range of concentrations of DDE for common tern eggs inside the AOC (mean 0.059 ± 0.0048 µg/g and range 0.030 – 0.090 µg/g) was similar to the mean and range of concentrations in common tern eggs collected outside the AOC (mean 0.084 ± 0.015, and range 0.036 – 0.27 µg/g), however the sample with the highest DDE concentration (0.272 µg/g) was from outside the AOC (Table 21). These concentrations are lower than reported in Karwowski (1992) for tern eggs collected between 1986 and 1989 from the same geographic area of the St. Lawrence River outside the AOC (Range 0.670 – 3.30 μg/g) which indicates that concentrations of DDE have declined in the upper St. Lawrence River over the past 25-28 years. Weseloh *et al.* (1989) examined organochlorines in common tern eggs collected in 1981 across the Great Lakes and their highest range of DDE concentrations were found in Lake Ontario (1.31 – 4.22 μg/g, n = 10) while the lowest range was reported in the Detroit River (0.59 – 1.36 μg/g).

Heptachlor epoxide

There are limited field and/or laboratory studies that report heptachlor epoxide concentrations in wildlife. Blus *et al.* (1984) reported reduced nest success in Canada geese (*Branta canadensis*) when egg concentrations were above 10 μg/g. However, American kestrels feeding on contaminated prey exhibited reduced nest success when egg concentrations exceeded 1.5 μg/g (*In* Elliot and Bishop, 2011). In the present study, the range of heptachlor epoxide concentrations in osprey, herring gull, and tern eggs are lower than those reported to have negative effects.

Osprey: Heptachlor epoxide concentrations in osprey egg samples were detected in only two osprey egg samples inside the AOC and in one sample outside the AOC. Concentrations were similar among both sites (Table 19). In osprey eggs collected throughout the Great Lakes Basin between 1991 – 1995, Martin *et al.* (2003) reported a range of heptachlor epoxide concentrations between ND – 0.056 μg/g.

Herring Gull: In the herring gull eggs of this study, heptachlor epoxide concentrations were low (n = 2, range 0.007 – 0.04 μg/g), yet are slightly higher than the most recent CWS herring gull egg collection from Strachan Island (2013; S. de Solla pers. comm.) where the concentration was 0.0064 μg/g (n = 1; 13 egg composite) (Table 20). Gilman *et al.* (1977) analyzed heptachlor epoxide in herring gull eggs collected across the Great Lakes in 1974-75 and reported mean concentrations of 0.12 μg/g (Lake Ontario), 0.14 μg/g (Lake Erie), 0.12 μg/g (Lake Huron), 0.14 μg/g (Lake Superior), and 0.16 μg/g (Lake Michigan), again all lower than concentrations known to impact reproduction. Similarly, Braune and Nortstrom (1989) reported mean heptachlor epoxide concentrations in herring gull eggs from Snake Island, Lake Ontario (collected in 1985) of 0.09 μg/g. Similarly, at Strachan Island adjacent to the Massena/Akwesasne AOC, Weseloh *et* *al.* (2006) reported a mean heptachlor epoxide concentration of 0.0156 μg/g, averaged over the years 1998 – 2002; higher than reported in the current study.

Common Tern: Although there was no significant difference in heptachlor epoxide concentrations in tern eggs from inside versus outside the AOC (Table 21), one egg sample collected inside the AOC had a concentration of 0.0475 μg/g which is 15 times higher than the mean heptachlor epoxide concentrations for inside or outside the AOC. The mean heptachlor epoxide concentrations inside and outside the AOC were, 0.003 ± 0.0002 μg/g and 0.004 ± 0.0006 μg/g respectively (Table 21). Karwowski (1992) reported a mean concentration of 0.015 ± 0.006 from the same colony as our outside AOC site. Similar to the other contaminants detected in terns, heptachlor epoxide concentrations have declined since the late 1980s.

Hexachlorobenzene (HCB)

HCB has been reported to reduce chick survival when maternal HCB egg concentrations exceeded 6.2 μg/g in captive bred Japanese quail (*Coturnix coturnix*) that were fed 20 μg/g for 90 days (Vos *et al.* 1971). Further, Vos *et al.* (1971) reported a no observed adverse effects level (NOAEL) on Japanese quail reproduction at HCB egg concentrations between 0.35 – 4.4 μg/g. Furthermore, Braune and Norstrom (1989) reported a mean HCB concentration of 0.10 μg/g in herring gull eggs collected at Snake Island, Lake Ontario in 1985. Again, the concentrations documented for osprey, herring gull, and common terns in the present study are below the toxicity thresholds described above (Table 19, Table 20, Table 21).

Osprey: HCB was detected in only one osprey egg sample inside the AOC (0.004 μg/g; Table 19). In osprey eggs collected throughout the Great Lakes Basin between 1991 – 1995, Martin *et al.* (2003) report a range of HCB concentrations between ND – 0.059 μg/g.

Herring Gull: In the current study, we report HCB egg concentrations in herring gulls of (n =2) 0.004 – 0.007 μg/g (Table 20), similar to that reported for Strachan Island herring gulls in 2013 (0.0123 μg/g; S. de Solla pers. comm.). Gilman *et al.* (1977) analyzed HCB in herring gull eggs collected across the Great Lakes in 1974-75 and reported mean concentrations of 0.19 μg/g (Lake Ontario), 0.11 μg/g (Lake Erie), 0.14 μg/g (Lake Huron), 0.11 μg/g (Lake Superior), and

0.04 μg/g (Lake Michigan). At Strachan Island, adjacent to the Massena/Akwesasne AOC, Weseloh *et al.* (2006) reported a higher mean HCB concentration in herring gull eggs of 0.0126 μg/g collected between 1998 – 2002.

Common Tern: Mean HCB concentration in tern eggs from inside the AOC (0.003 ± 0.0002) was significantly lower ($\rho = 0.007$) than outside the AOC (0.004 ± 0.0004; Table 21). Overall, the range of HCB concentrations observed in the current study inside and outside the AOC (0.0012 – 0.0040 μg/g and 0.0028 – 0.0069 μg/g, respectively) are lower than those reported in Karwowski (1992) in common tern eggs outside the AOC (mean: 0.02 ± 0.01 μg/g; range: 0.01 – 0.07 μg/g). In addition, Weseloh *et al.* (1989) documented HCB concentrations in tern eggs collected from eastern Lake Ontario in 1981 and reported a range of ND – 0.10; n = 10.

Dioxins and Furans

Dioxins and furans were analyzed in only n = 2 herring gull egg composites (outside the AOC) and n = 4 common tern egg samples (inside the AOC) because of limited sample mass. In common tern, all dioxins and furans were below detection limits. Several dioxins and furans were detected in herring gulls (See table 13) but only at trace levels (≤ 0.00002 μg/g). Similarly. S. De Solla (pers. comm.) found similar trace concentrations of Dioxins/Furans in Strachan Island herring gull eggs (n =1; 13 egg composite) in 2013. These levels are well below known toxicity thresholds for dioxins and furans (Harris and Elliot 2011). However, it is important to note that Lorenzen *et al.* (1996) suggest common tern embryos may be more susceptible to the synergistic effects of multiple dioxin/furans than indicated by known effects of individual dioxin/furans.

Table 19. Contaminants (µg g^{-1} ww) in osprey (*Pandion haliaetus*) eggs collected inside and outside the Massena/Akwesasne AOC in 2014. Note: NA= Not applicable due to small sample size; NS = Not significant.

	Inside AOC (n=3)		Outside AOC (n=3)		
Contaminant	Range	Mean ± SE	Range	Mean ± SE	p
Total PCBs	0.73 – 2.37 (3)	1.55 ± 0.47	0.48 – 2.84 (3)	1.37 ± 0.74	NS
Hg	0.13 – 0.44 (3)	0.23 ± 0.10	0.07 – 0.11 (3)	0.09 ± 0.01	p = 0.0495
Fluoride	4.1 – 6.3 (2) [1]	5.2 ± 1.10	17 – 23 (3)	19.0 ± 2.0	NA
DDE	0.12 – 1.01 (3)	0.44 ± 0.29	0.13 – 0.20 (3)	0.16 ± 0.02	NS
Heptachlor epoxide	0.006 – 0.01 (2)	0.01 ± 0.003	0.01 (1)		NA
Hexachlorobenzene	0.004 (1)				NA
Lipids (%)	3.17 – 4.65 (3)	3.70 ± 0.48	3.35 – 3.71 (3)	3.55 ± 0.11	NS

[1] Fluoride was ND in the third osprey sample inside the AOC

Table 20. Contaminants (µg g^{-1} ww) in herring gull (*Larus argentatus*) eggs collected inside and outside the Massena/Akwesasne AOC in 2014. Note: NA= Not applicable due to small sample size; NS = Not significant.

Contaminant	Units		Upstream of AOC at West Crossover Island (n=1)	Inside AOC at Strachan Island or Bergin Rocks (n=1)	Downstream of AOC at D41 (n=1)	Significance
Total PCBs	mg/kg	ppm	1.03	2014 Data from CWS in preparation[2]	3.93	NA
Hg	mg/kg	ppm	0.326		0.523	NA
Fluoride	mg/kg	ppm	2.6		ND	NA
DDE [1]	µg/g	ppm	0.238		0.4980	NA
Heptachlor epoxide [1]	µg/g	ppm	0.0065		0.0408	NA
Hexachlorobenzene	µg/g	ppm	0.00383		0.00731	NA
TCDF	ng/kg	ppt	6.3		19.0	NA
PeCDF	ng/kg	ppt	20.0		ND	NA
HxCDF	ng/kg	ppt	9.4		21.0	NA
HpCDD	ng/kg	ppt	ND		6.6	NA
OCDD	ng/kg	ppt	15.0		62.0	NA
Lipids	%	-	3.87		5.21	NA

[1] Heptachlor epoxide and DDE values were flagged with a Z qualifier denoting chromatographic interference due to PCB co-elution.
[2] 2013 results indicate 3.03 mg/kg ww Total PCBs (8.72% lipids). Hg results reported in dw and not comparable to Table 20. 2013 results on file with SRMT, but not included in Table 20 demonstrating 2014 environmental conditions.

Table 21. Contaminants (µg g^{-1} ww) in common tern (*Sterna hirundo*) eggs collected inside and outside the Massena/Akwesasne AOC in 2014. Note: NA= Not applicable due to small sample size; NS = Not significant.

	Inside AOC (n=15)		Outside AOC (n=15)		
Contaminant	Range (n)	Mean ± SE	Range (n)	Mean ± SE	p
Total PCBs	0.47 – 3.95 (15)	0.96 ± 0.23	0.24 – 1.05 (15)	0.49 ± 0.058	p = 0.0015
Mercury	0.137 – 0.569 (15)	0.38 ± 0.032	0.19 – 0.77 (14)	0.37 ± 0.045	NS
p,p'-DDE	0.030 – 0.090 (15)	0.059 ± 0.0048	0.036 – 0.27 (15)	0.084 ± 0.015	NS
Hexachlorobenzene	0.0012 – 0.0040 (13)	0.003 ± 0.0002	0.0028 – 0.0069 (11)	0.004 ± 0.0004	p = 0.007
Heptachlor epoxide	0.0017 – 0.048 (15)	0.007 ± 0.003	0.0016 – 0.0057 (6)	0.004 ± 0.0006	NA
Lipids (%)	2.75 – 8.77 (15)	6.63 ± 0.36	4.24 – 7.99 (15)	5.95 ± 0.33	NS

Table 22. Adverse effects thresholds for dioxin-like compounds and PCB 126 in bird eggs.

Species	Effects Measured in Laboratory	Egg Concentration	Reference	Chemical
Common Tern	LOAEC	4.40 ppb (µg/kg) TEQ	EPA 2003	Dioxin-like compounds
Common Tern	Malformation and edema; reduced hatching success; crossed bill	44 ppb	Hoffman et al. 1998	PCB 126 (3,3',4,4',5-pentaCB)
Common Tern	LD50	65 ppb	Hoffman et al. 1998	PCB 126 (3,3',4,4',5-pentaCB)
Chicken	Malformation and edema	0.3 ppb (ng/g)	Hoffman et al. 1998	PCB 126 (3,3',4,4',5-pentaCB)
Chicken	LD50	0.4 ppb	Hoffman et al. 1998	PCB 126 (3,3',4,4',5-pentaCB)
American Kestrel	Malformation and edema	2.3-23 ppb	Hoffman et al. 1998	PCB 126 (3,3',4,4',5-pentaCB)
American Kestrel	LD50	104 ppb	Hoffman et al. 1998	PCB 126 (3,3',4,4',5-pentaCB)

LOAEC – Lowest observable adverse effect concentration
LD50 – Lethal concentration that will kill half of the embryos tested

Table 23. Toxicological effects thresholds associated with egg concentrations of PCBs in various bird species.

Endpoint	Species	Egg PCB Concentration Associated with Effect (ppm ww)	Reference
LOAEC reduced hatchability	Chicken	1.3	Chapman 2003
NOAEC productivity (young fledged per nest)	Bald eagle	4	Bowerman *et al*. 2003
NOAEC reproductive success	Double-crested Cormorant	13.6	Custer *et al*. 1999
No effect reproduction	Screech owl	4-18	McLane and Hughes 1980
Mortality	Double-crested Cormorant	4.4-14.8	Tillitt *et al*. 1992
Reduced hatchability	Ring dove	16	Peakall and Peakall 1973
Reduced hatchability	Common Tern	7.6-10	Hoffman *et al*. 1993
Reduced hatchability	Forster's tern	22	Kubiak *et al*. 1989
Reduced reproduction	American kestrel	34.1	Fernie *et al*. 2001a, b
Impaired disease resistance	Mallard	25	Friend and Trainer (1970)
No reproductive effects	Mallard	150	Haseltine and Prouty(1980)
Eggshell thinning	Mallard	150	Haseltine and Prouty(1980)

NOAEC = No observed adverse effect concentration
LOAEC - Lowest observed adverse effect concentration

3.6 Eggshell Thickness

In the current study, we measured eggshell thickness to the nearest 0.001 mm. Three measurements were taken at each of three locations on the shell and averaged. Mean thickness was compared among all eggs collected (osprey n=6, herring gull n=26, common tern n=30) (Table 24, Table 25, Table 26, Table 27). Eggshell thickness was not significantly different between eggs collected inside and outside the AOC for herring gulls, osprey, or common terns. In fact, only for herring gulls was the mean eggshell thickness lower inside the AOC as compared to the mean eggshell thickness outside the AOC, but the difference was very small (0.001 mm). Mean eggshell thicknesses inside and outside the AOC (respectively) were (mean ± SE): Herring gull 0.315 ± 0.022 mm and 0.316 ± 0.021 mm, Osprey 0.483 ± 0.0231 mm and 0.465 ± 0.010 mm, and Common tern 0.171 ± 0.003 mm and 0.166 ± 0.002 mm. Egg shell thickness may vary with the order in which the eggs were laid. The first laid egg may be thicker than subsequent eggs (Nisbet 1982, Custer *et al.* 1983). In this study, the laying order of each egg was not known.

In the current study, the contaminants of concern (based on observed concentrations) that may have a negative impact on eggshell thickness are primarily PCBs and DDE. Weseloh *et al.* (1991) established a TRV of 5.0 µg/g (ppm) for PCBs, which was the No Effects Concentration (NOEC) for shell thinning and/or embryonic deformities in herring gulls. In the current study, the maximum PCB concentrations we report are 2.84 µg/g in osprey eggs, 3.93 µg/g in herring gull eggs, and 3.95 µg/g in common tern eggs. All of these concentrations are lower than the NOEC TRV of 5.0 µg/g (ppm) for PCBs established by Weseloh *et al.* (1991).

For DDE, the authors are not aware of a toxicity reference value (TRV) for any of the target bird species in the current study, but a TRV of 10 µg/g (ppm) was established for the double-crested cormorant where no reproductive effects were observed (Fox and Bowerman 2005). More conservatively, a TRV of 3.5 µg/g was established where eggshell thinning occurred in bald eagles (Wiemeyer *et al.* 1984), yet Garcelon and Thomas (1997) calculate a TRV of 8.0 µg/g where bald eagle reproductive impairment occurs. DDE concentrations reported in the current study of 0.030 – 1.01 µg/g for all species combined are well below DDE TRVs described above.

Published accounts for common tern eggshell thickness data from 1973 reported means ranging between 0.166 – 0.180 mm from a tern colony at Gray's Beach in Cape Cod Bay (Nisbet 1982). These data are similar to our results. However, tern eggshell data from coastal Rhode Island and New York from 1980 and 1981 (Custer *et al.* 1983) reported a higher range of means of 0.188 – 0.213 mm or 4-15% thicker than our results and those of Nisbet (1982). Similarly, Weseloh *et al.* (1989) reported eggshell thickness from Lake Ontario and Lake Erie (collected 1981) of 0.188 – 0.213 mm, again thicker than reported in the current study. Furthermore, Burger *et al.* (1995) reported values of 0.353 – 0.462 mm from Barnegat Bay, New Jersey and Cedar Beach, New York (1981 and 1991, respectively), which may suggest that values in the current study are lower than regional averages and/or that recovery of eggshell thickness in common terns on the St. Lawrence River has been slow.

In herring gulls, values for eggshell thickness across the Great Lakes and Europe were similar between the years 1973 – 1983 with averages ranging from 0.332 – 0.368 mm (Teeple 1977, Weseloh *et al.* 1990, Ewins *et al.* 1992, Weseloh *et al.* 1994); 5 – 10% thicker than reported in the current study and possibly up to 20% thinner than pre-1947 levels. The largest value we found was 0.410 mm, from Appledore Island at Isle of Shoals, several miles off the Maine/New Hampshire coast but this value was cited as not significantly different than pre-1947 levels (Szaro *et al.* 1979). Importantly, herring gull eggs appear less impacted than common tern eggs within the St. Lawrence River (current study), and this may reflect differences in diet. In general, herring gulls forage primarily on echinoderms and mollusks (Pierotti and Annett 1991, Good 1992) which bioaccumulate less contaminants than prey fish which constitute the bulk of tern diets (Nisbet 2002).

For osprey, pre-1947 shell thickness data reported a mean of 0.505 mm (Anderson and Hickey 1972); 23 – 24 % thicker than reported in the current study. Interestingly, in the 1970s, a non-migratory population of osprey in Florida had up to 15% thicker eggshells than values of migratory osprey populations pre-1947 (Ogden *et al.* 1974, Wiemeyer *et al.* 1988), which suggests little exposure to contaminants in that region. Furthermore, migratory osprey (1970s) were 3-27% thinner than pre-1947 migratory individuals, likely because of high contaminant burdens (Wiemeyer *et al.* 1975, Spitzer *et al.* 1978, Wiemeyer *et al.* 1988). Despite these differences over time, current shell thickness reported in the current study for osprey are within ranges recorded across the Atlantic coast between 1998 and 2002 (Clark *et al.* 2001, Rattner *et al.* 2004, Toschik *et al.* 2005). Lastly, although osprey consume larger (and likely more contaminated) prey than either herring gull or terns, they appear less impacted by contaminants currently in the St. Lawrence River, suggesting either a greater resilience to the effects of contaminants on eggshell thinning or that DDE levels have decreased to the point where they are no longer a major factor in determining eggshell thickness.

Table 24. Eggshell thickness (mm) for osprey, herring gull, and common tern from the St. Lawrence River inside and outside the AOC in 2014. All inside versus outside AOC comparisons for a given species were not significantly different.

Species	Inside or Outside AOC	Sites	N	Minimum (mm)	Maximum (mm)	Mean (SE) (mm)
Osprey	Outside (upstream)	Lake St. Lawrence and Thousand Islands	3	0.457	0.476	0.465 (0.006)
	Inside	Lake St. Lawrence and Akwesasne	3	0.441	0.521	0.483 (0.023)
Herring gull	Outside (upstream)	West Crossover	13	0.268	0.346	0.316 (0.006)
	Outside (downstream)	D41 (Lake St. Francis)	13	0.278	0.365	0.315 (0.006)
Common tern	Outside (upstream)	Navigation cell 156	30	0.152	0.194	0.166 (0.002)
	Inside	Eisenhower Mooring Cells (EMC)	30	0.138	0.200	0.171 (0.003)

Table 25. Eggshell thickness (mm) for osprey, 1970 – Present, and associated concentrations of DDE and PCBs (µg/g ww).

Year(s)	Location	Mean thickness (mm)	n	DDE conc. (µg/g)	PCBs (µg/g)	Reference
1970	Florida Bay,	0.56	11	1.18	1.43	Ogden *et al.* 1974
1972-73	Coeur d'Alene Lake, Idaho	0.420	11	7.4	0.82	*In* Wiemayer *et al.* 1988
1976	CT, NY	0.442	7	29.1	83.3	Spitzer *et al.* 1978
1976	CT, NY	0.436	10	59.6	130	Spitzer *et al.* 1978
1976	CT, NY	0.411	35	113	144	Spitzer *et al.* 1978
1976-77	Flathead Lake, MT	0.414	7	2.9 – 37.0	0.98 – 12.0	*In* Wiemayer *et al.* 1988
2000	Chesapeake Bay, Baltimore Harbor	0.499	14	0.443	7.25	Rattner *et al.* 2004
2002	Delaware Bay	0.454	12	1.77	8.68	Toschik *et al.* 2005
2002	Delaware Bay, Delaware River	0.527	12	0.656	4.38	Toschik *et al.* 2005
2014	St. Lawrence River, Inside AOC	0.483	3	0.44	1.55	Current Study
2014	St. Lawrence River, Outside AOC	0.465	3	0.16	1.37	Current Study

Table 26. Eggshell thickness (mm) for herring gull, 1970 – Present, and associated concentrations of DDE and PCBs (µg/g ww).

Year(s)	Location	Mean thickness (mm)	N (egg-shells)	DDE conc. (µg/g)	PCBs (µg/g)	Reference
1973	Brothers Island, Lake Ontario	0.339	13			Teeple 1977
1977	Appledore Island, ME	0.41	30	1.94	7.76	Szaro *et al.* 1979
1978	Fighting Island, Lake Erie	0.342	11	9.4	12.0	Weseloh *et al.* 1990
1979	Niagara River, Lake Ontario	0.36	10	4.0	50.0	Weseloh *et al.* 1990
1980	Channel Island, Lake Huron	0.345	10			Ewins *et al.* 1992
1983	Lake Linden, Lake Superior	0.341	12			Weseloh *et al.* 1994
2014	St. Lawrence River, Outside AOC (upstream)	0.316	13	0.37 (n = 2)	2.48 (n = 2)	Current Study
2014	St. Lawrence River, Outside AOC (downstream)	0.315	13	0.24-0.50 (n=2)	2.48 (n=2)	Current Study

Table 27. Eggshell thickness (mm) for common tern, 1970 – Present, and associated concentrations of DDE and PCBs (μg/g ww).

Year(s)	Location	Mean thickness (mm)	N (egg-shells)	DDE conc. (μg/g)	PCBs (μg/g)	Reference
1973	Cape Cod Bay, Gray's Beach	0.18	10	0.59	5.28	Nisbet 1982
1973	Cape Cod Bay, Gray's Beach	0.166	10	0.66	0.052	Nisbet 1982
1980	Providence, RI	0.193	9	0.67	8.23	Custer *et al.* 1983
1980	Great Gull Island, NY	0.190	25	0.72	4.48	Custer *et al.* 1983
1980	Cedar Beach, NY	0.203	9	0.50	2.65	Custer *et al.* 1983
1981	Leslie St. Split, Lake Ontario	0.203	10	2.46	10.4	Weseloh *et al.* 1989
1981	Port Colbourne Light House, Lake Erie	0.213	10	0.95	4.76	Weseloh *et al.* 1989
1989	St. Lawrence upriver, Outside AOC	0.203	10	3.12	0.76	Karwowski 1992
	Oneida Lake, NY	0.192	10	1.89	0.53	Karwowski 1992
1991	Barnegat Bay, NY	0.452	36			Burger *et al.* 1995
2014	St. Lawrence River, Outside AOC (upstream)	0.166	30	0.084 (n = 15)	0.49 (n = 15)	Current Study
2014	St. Lawrence River, Inside AOC	0.171	30	0.059 (n = 15)	0.96 (n = 15)	Current Study

4.0 LESSONS LEARNED

Field surveys of sentinel species nesting and the collection of eggs for contaminant analysis proceeded smoothly. The determination of productivity was not difficult for most species, although black terns represented a unique challenge. At the beginning of field surveys, we were considering fencing black tern nests with plastic mesh so that we could accurately determine the number of chicks hatched and fledged. However, these methods were used for this same purpose for herring gull nests in 2013 and predators apparently keyed in on the enclosures and killed all but two chicks from 48 nests. For this reason, we did not fence nests of black terns in either 2013 or in 2014. Because black tern chicks are very mobile shortly after hatching and leave the nest when disturbed, the determination of chick hatching and productivity is extremely difficult. In 2014, we monitored selected black tern nests with video cameras (*e.g.* GoPro cameras) and found this to be a very effective means to determine how many chicks were present in each nest. The cameras were allowed to run for one hour, during which time the adults and the chicks returned to the nest and were recorded. This method provided solid data on how many chicks were present in each nest, and if done quickly on clear and calm days, was not unduly disruptive to the nesting colony. In the future, this method may be used for other species such as pied-billed grebe, although they are so shy the cameras should be camouflaged so as not to be disruptive.

Productivity data were collected in 2013 and in 2014. Our sample sizes were larger in 2014. Two years of data provided much greater confidence in our results.

One concern of collecting eggs from sentinel species nests such as ospreys is that the egg collection will depress productivity. Grove *et al.* (2009) noted that this was rarely the case, and our results support that. The productivity of nests from which eggs were removed was nearly identical to nests that were left undisturbed.

5.0 SUMMARY AND RECOMMENDATIONS

Avian habitats are different inside and outside the AOC, with more man-made engineered habitat inside the AOC. Productivity is variable from year to year, but largely similar inside and outside the AOC. Populations of the species (common tern, herring gulls, osprey, bald eagle and black terns) monitored in 2013 and 2014 appear to be stable. There was no difference in eggshell thickness when compared inside to outside of the AOC. Incident rate of deformities are lower than in past years. Differences occur in contaminant levels inside and outside the AOC, but levels are lower than in earlier studies and below known adverse effects thresholds. Common tern eggs have significantly higher PCB levels inside the AOC, osprey eggs have higher mercury levels inside the AOC, and PCB concentrations in herring gulls downstream the AOC are at levels higher than reference sites and comparable to PCB concentrations inside the AOC (thus indicating transboundary impacts).

Sentinel species of the AOC and environs such as osprey and bald eagle are becoming increasingly common in recent years. These species are sensitive to both contaminants and to human disturbance. Protecting the habitats of these species is important to their continued recovery in and near the AOC. Eagles in particular are sensitive to human disturbance. Eagle nests should be monitored annually and protected. Field reconnaissance and /or surveys should be conducted in Akwesasne and surrounding environs to determine if golden eagle presence can be validated.

An Eagle and Osprey Management Plan should be developed for Akwesasne, collaborated between MCA and SRMT. These management plans will include recommendations for site-specific population, habitat, and threat assessments, along with conservation goals and actions necessary to protect the species and its habitat. A desktop analysis should be conducted to estimate what population numbers the current environment/habitat could support to develop conservation goals and metrics.

To gain further insight into contaminant levels of the AOC, efforts could be made to collect unviable eggs of bald eagles for contaminant testing. This is not an easy task, however, and would be made easier by constructing artificial eagle nesting platforms. Eagle platforms have been constructed in the Thousand Islands, and could be constructed on Lake St. Lawrence and Lake St. Francis as well.

Habitat for common terns is lacking downstream of the Moses-Saunders Power Dam, in Akwesasne. Sites formerly occupied by terns have been taken over by gulls or simply abandoned. Efforts to restore these sites could be beneficial to the regional tern population and contribute to their restoration in and near the AOC. Restoration of common tern nesting colonies downstream of the Moses-Saunders is not part of a current funded NYPA HIP project, and additional efforts and funding outside of current HIP projects would be needed to achieve common tern restoration in Akwesasne and Lake St. Francis. If tern nesting islands cannot be easily restored in Akwesasne, consideration should be given to artificial nesting platforms such as floating rafts or barges. Tern restoration efforts on Lake St. Lawrence have been remarkably successful, almost doubling the number of nesting pairs in ten years (Riveredge Associates 2014). However, the goal of 1400 nests has not yet been achieved, and HIP restoration efforts should be maintained until so.

A feasibility study should be conducted to determine if it is possible to restore the historic black tern nesting site in WHWMA. The well-established and productive colonies of Akwesasne could provide a source of birds seeking new nesting areas. This bird is an endangered species in New York and additional efforts should be made to stabilize the population. In addition, further site surveys of black tern nesting habitat in Snye Marsh should be made to identify and map invasive species such as Phragmites that may reduce and eventually limit available nesting habitat for this rare species. Now that nest sites for this species are clearly identified, they should be monitored periodically to detect any changes in the population. NYSDEC monitors black tern colonies at least every five years. This level of monitoring should be the bare minimum, and additional active management should be considered if causes of low productivity are identified. In addition, floating nesting platforms could be installed for black terns to provide additional nesting habitat and protect nests from boat wake wash over.

The common tern HIP and the osprey HIP were conceived and implemented precisely because habitat for these species was lacking in and adjacent to the AOC. Continued efforts should be made to restore these species to the area and to increase the amount of suitable nesting habitat available for these species.

If great blue herons establish a nesting colony in the AOC, sampling of heron eggs may be warranted to provide comparative data to the colonies of the St. Lawrence River examined by Champoux *et al.* (2002, 2006, 2010).

In addition, to further investigate the pathway from sediment to insects to avian resources, a tree swallow study similar to Bishop *et al.* (1999), Martinovic *et al.* (2003a and 2003b), or Custer and Custer (2013) could be considered for the Superfund site on the lower Grasse River, and overall Massena/Akwesasne AOC monitoring. Historic tree swallow egg PCB contaminant concentrations was found to be highest in Akwesasne (Bishop et al., 1999) while highest PCB detection in 16-day-old tree swallows were found from nestlings near the Grasse River.

Finally, a public outreach program would be useful to promote cultural significance and avian population conservation awareness. School instruction could include cultural use and meaning of avian feathers in Kastowas, ceremony, regalia, and social dances depicting birds (i.e. robin, pigeon, duck, etc.). Video and other visual tools such as “The Call of the Osprey” (https://www.youtube.com/watch?v=CcfNDUU7jTI) could be used as well to demonstrate significance of St. Lawrence River habitat for avian species.

6.0 LITERATURE CITED

Akwesasne Task Force on the Environment (ATFE). 2001. Cultural resource study. Special supplement: results of the cultural resource study on the re-licensing of the St. Lawrence – FDR Power Project.

Alcoa Inc. 2001. Comprehensive Characterization of the Lower Grasse River (CCLGR). Grasse River study area. Massena, New York.

Alcoa Inc. 2005. Remedial Options Pilot Study Work Plan. Grasse River Study Area. Massena, New York. February 2005.

Alcoa Inc. 2006. Draft Remedial Options Pilot Study Documentation Report. Grasse River Study Area, Massena, New York. Volume 1. May 2006.

Alcoa Inc. July 2012. Analysis of alternatives report. Grasse River study area. Massena, New York.

Anderson, D. W., and J. J. Hickey. 1972. Eggshell changes in certain North American birds. Proc. Int. Ornithol. Congr. 15:514–540.

Anderson, D.W. and J.J. Hickey. 1972. Eggshell changes in certain North American birds. Pages 514-540 in K. H. Voous, editor. Proceedings of the XVth International Ornithological Congress, The Hague, Netherlands 30 Aμgust-5 September 1970. E. J. Brill, Leiden. viii, 745 pp.

Arcadis. 2008. General Motors Powertrain Site, Massena, New York, Results of 2008 Fish Collection Activities to Evaluate Fish Consumption Advisory in Remediated Cove, St Lawrence River. Prepared for General Motors Powertrain Site. December 19.

Baird, C. J., L. H. Harper, R. A. Lavoie,. and L. M._Campbell. 2012. Mercury in common terns *(Sterna hirundo)* breeding along the St. Lawrence River: a comparison between summer and winter habitat. 55th Conference of the International Association for Great Lakes Research (IALGR), Cornwall, Ontario, Canada

Becker, PH, RW Furness, D Henning. 1993. Mercury dynamics in young common tern (Sterna hirundo) chicks from a polluted environment. Ecotoxicology. 2:33-40.

Bishop, C. A., M. D. Koster, A. A. Chek, D. J. T. Hussell and K. Jock. 1995. Chlorinated hydrocarbons and mercury in sediments, red-winged blackbirds (*Agelaius phoeniceus*) and tree swallows (*Tachycineta bicolor*) from wetlands in the Great Lakes-St. Lawrence River basin. Environmental Toxicology and Chemistry 14: 491-50.

Bishop, C. A., N.A. Mahony, S. Trudeau, K. Pettit. 1999. Reproductive success and biochemical effects in tree swallows *(Tachycineta bicolor)* exposed to chlorinated hydrocarbon contaminants in wetlands of the great lakes and St. Lawrence river basin, USA and Canada. Environmental Toxicology and Chemistry. 18: 263–271.

Blasland, Bouck & Lee, Inc (BBL). 1995. Draft non-time critical removal action documentation report. Volume II (appendices). Grasse River study area. Massena, New York. Prepared for Aluminum Company of America.

Blues, L.J. 2011. DDT, DDD, and DDE in birds. In Environmental contaminants in biota: interpreting tissue concentrations. Beyer, W. N., & Meador, J. P. (Eds.). Boca Raton, Florida: CRC Press. Pp 425 -440.

Blus, L. J., C. J. Henny, D. J. Lenhart, and T. E. Kaiser. 1984. Effects of heptachlor- and lindane-treated seed on Canada geese. J. Wildl. Manage. 48:1097–1111.

Bond, A., A.W. Diamond. 2009. Mercury concentration in seabird tissues from Machias Seal Islands, New Brunswick, Canada. Science of the Total Environment 407:4340-4347

Braune, B.M., R.J. Norstrom. 1989. Dynamics of organochlorine compounds in herrings gulls: III. Tissue distribution and bioaccumulation in Lake Ontario gulls. Environmental toxicology and chemistry. 8:957-968.

Buehler, D. A. 2000. Bald Eagle (*Haliaeetus leucocephalus*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/506

Burger, J., K. Viscido and M. Gochfeld. 1995. Eggshell thickness in marine birds in the New York Bight - 1970s to 1990s. Archives of Environmental Contamination and Toxicology 29:187-191

Burger, J., M. Gochfeld. 2007. Risk, mercury levels, and birds: Relating adverse laboratory effects to field biomonitoring. Environmental Research 75:160-172.

Burgess N. 2005. Mercury in biota and its effects. In: M Parsons, Percival J, editors. Mercury: sources, measurements, cycles, and effects. Mineralogical Association of Canada, Short Course Series Halifax, NS;4:235–46.

Champoux, L., J. Rodrigue, J.L. DesGranges, S. Trudeau, A. Hontela, M. Boily. P.A. Spear. 2002. Assessment of contamination and biomarker responses in two species of Herons on the St. Lawrence River. Environmental Monitoring and Assessment 79: 193–215.

Champoux, L, J. Rodrigue. S. Trudeau, M. Boily, P.A. Spear, A. Hontela. 2006. Contamination and biomarkers in the Great Blue Heron, an indicator of the state of the St. Lawrence River. Ecotoxicology 15: 83–96.

Champoux, L., J. Moisey, D.G.C. Muir. 2010. Polybrominated diphenyl ethers, toxaphenes, and other halogenated organic pollutants in great blue heron eggs. Environmental Toxicology and Chemistry, 29:243–249.

Chapman, J. 2003. Toxicity reference values (TRVs) for mammals and birds based on selected Aroclors. Memorandum dated March 6, 2003 to Shari Kolak, U.S. Environmental Protection Agency Region 5.

Clark, K.E., W. Stansley and L.J. Niles. 2001. Changes in contaminant levels in New Jersey osprey eggs and prey, 1989 to 1998. Archives of Environmental Contamination and Toxicology 40:277-284.

Custer, T.W., R.M. Erwin and C. Stafford. 1983. Organochlorine residues in common tern eggs from nine Atlantic Coast colonies, 1980. Colonial Waterbirds 6:197-204.

Custer, T.W., C.M. Custer, R.K. Hines, S. Gutreuter, K.L. Stromborg, P.D. Allen and M.J. Melancon. 1999. Organochlorine contaminants and reproductive success of double-crested cormorants from Green Bay, Wisconsin, USA. Environ. Toxicol. Chem. 18 (6): 1209 - 1217.

Custer, T.M and C.M. Custer. 2013. Birds as indicators of contaminant exposure in the Great Lakes. Great Lakes Restoration Initiative (GLRI) Project 80. United States Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. http://www.umesc.usgs.gov/wildlife_toxicology/glri_project80.html

Donatuto, J., and B.L. Harper. 2008. Issues in evaluating fish consumption rates for Native American Tribes. Risk Analysis 28(6):1497-1506.

Elliot, J.E., and C.A. Bishop. 2011. Cyclodiene and other organochlorine pesticides in birds. In Environmental contaminants in biota: interpreting tissue concentrations. Beyer, W. N., & Meador, J. P. (Eds.). Boca Raton, Florida: CRC Press. Pp 447 – 467

Ecology and Environment, Inc. (E&E). 2008. Summary of delisting criteria and status for NYS areas of concern. Submitted to Great Lakes National Program Office (GLNPO) December 16, 2008 for approval.

Environment Canada (EC), Ontario Ministry of Environment (OME), Ontario Ministry of Natural Resources (OMNR), New York State Department of Conservation (NYSDEC), and United States Environmental Protection Agency (USEPA). 1994. The St. Lawrence River Area of Concern: Cornwall-Lake St. Francis & Massena remedial action plans: stage 1 summary. A binational statement. ISBN 0-662-20930-3.

Evers DC, Kaplan JD, Meyer MW, Reaman PS, Braselton WE, Major A, Burgess NW, Scheuhammer AM. 1998. Geographic trend in mercury measured in common loon feathers and blood. Environmental Toxicology and Chemistry. 17:173-83.

Evers, D.C., K.M. Taylor, A. Major, R.J. Taylor, R.H. Poppenga, A.M. Scheuhammer. 2003. Common loon eggs as indicators of methylmercury availability in North America. Ecotoxicology. 12:69-81.

Evers, DC, Savoy LJ, DeSorbo CR, Yates DE, Hanson W, Taylor KM, Siegel LS, *et al*. 2008. Adverse effects from environmental mercury loads on breeding common loons. Ecotoxicology. 17:69-81.

Ewins, P.J., D.V. Weseloh and P. Mineau. 1992. Geographical distribution of contaminants and productivity measures of herring gulls in the Great Lakes: Lake Huron 1980. Journal of Great Lakes Research 18:316-330.

Fernie, K.J., J.E. Smits, G.R. Bortolotti, and D.M. Bird. 2001a. Reproduction success of American kestrels exposed to dietary polychlorinated biphenyls. *Environ. Toxicol. Chem.* 20:776-781.

Fernie, K.J., J.E. Smits, G.R. Bortolotti, and D.M. Bird. 2001b. In Ovo exposure to polychlorinated biphenyls: reproductive effects on second-generation American kestrels. *Arch. Environ. Contam. Toxicol*. 40:544-550.

Fimreite, N. 1974. Mercury contamination of aquatic birds in northwestern Ontario. Journal of Wildlife Management. 38, 120–131.

First people – The legends. Website accessed January 8, 2016. http://www.firstpeople.us/FP-Html-Legends/Legends-IL.html#Iroquois

Fisher, S. A., G. R. Bortolotti, K. J. Fernie, D. M. Bird, and J. E. Smits. 2006. Behavioral variation and its consequences during incubation for American kestrels exposed to polychlorinated biphenyls. Ecotoxicology and Environmental Safety. 63:226–235.

Forti, A., K. G. Bogdan, E. Horn. 1995. Health risk assessment for the Akwesasne Mohawk population from exposure to chemical contaminants in fish and wildlife. Albany, NY: New York State Department of Health. New York State Department of Health Center for Environmental Health Bureau of Toxic Substance Assessment; 1995.

Fox, G. 2001. Wildlife as sentinels of human health effects in the Great Lakes-St. Lawrence Basin. Environmental Health Perspectives. 109: 853-861.

Fox G. A., W.W. Bowerman. 2005. Setting delisting goals for wildlife deformities and reproduction at great lakes areas of concern. Report to International Joint Commission, Great Lakes Regional Office, Windsor, Ontario.

French, J. B., I. C. Nisbet, and H. Schwabl. 2001. Maternal steroids and contaminants on common tern eggs: a mechanism of endocrine disruption? Comp Biochem Physiol C Toxicol Pharmacol. 128:91-98.

Friend, M. and D. O. Trainer. 1990. Polychlorinated biphenyl: interaction with duck hepatitis virus. Science. 170:1314.

Garcelon, D.K., and N.J. Thomas. 1997. DDE poisoning in an adult bald eagle. Journal of Wildlife Diseases. 33: 299-303.

Garibaldi, A., and N. Turner. 2004. Cultural keystone species: Implications for ecological conservation and restoration. Ecology and Society, 9(3):1-15.

Gilman, A.P., G.A. Fox, D.B. Peakall, S.M. Teeple, T.R. Carroll, G.T. Haymes. 1977. Reproductive parameters and egg contaminant levels of great lakes herring gulls. Journal of Wildlife Management. 41:458-468.

Good, T. P. 1992b. Herring gulls *Larus argentatus* and great black-backed gulls *Larus marinus* as rocky-shore predators: patterns and implications for intertidal communities. Master's Thesis. Univ. New Hampshire, Durham.

Grasman, K. A., G. A. Fox, P. F. Scanlon, and J. P. Ludwig. 1996. Organochlorine-associated immunosuppression in prefledgling Caspian terns and herring gulls from the Great Lakes: an ecoepidemiological study. Environ. Health. Perspect. 104 (Suppl 4):829–842.

Grove, R. A., C. J. Henny, J. L. Kaiser. 2009. Osprey: Worldwide sentinel species for assessing and monitoring environmental contamination in rivers, lakes, reservoirs, and estuaries. Journal of Toxicology and Environmental Health, Part B, 12:25-44.

Harper L.H. and J.L. Jock. September2014. Avian Interim Status Report: Avian Habitat, Populations, Reproduction and Contaminants In and Near the Massena/Akwesasne St. Lawrence River Area of Concern (AOC). GL-97221310. 41 pp.

Harper, L. H., A. Johnson, and N. Eldblom. 1996. Results of field surveys for rare, threatened and endangered species and significant occurrences of natural communities on New York Power Authority lands at the St. Lawrence-FDR Power Project, Massena, New York, Phase Two Report. New York Natural Heritage Program. Latham, New York. 71 pp.

Harris, M.L., J.E. Elliot. 2011. Effects of polychlorinated biphenyls, dibenzo-p-dioxins, and dibenzofurans, and polybrominated diphenyl ethers in wild birds. In Environmental contaminants in biota: interpreting tissue concentrations. Beyer, W. N., & Meador, J. P. (Eds.). Boca Raton, Florida: CRC Press. Pp 477-527.

Harris, S.G. 2000. Risk analysis: Changes needed from a Native American perspective. Human and Ecological Risk Assessment, 6(4):529-535.

Haseltine, S.D., Prouty, R.M. 1980. Aroclor 1242 and reproductive success of adult mallards (*Anas platyrhynchos*). Environmental Research, 23: 29 - 34.

Heath, S. R., E. H. Dunn and D. J. Agro. 2009. Black Tern (*Chlidonias niger*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/147

Heinz, G.H., D.J. Hoffman. 2003. Embryotoxic thresholds of mercury: Estimates from individual mallard eggs. Archives of Environmental Contaminants and Toxicology. 44: 257-264.

Hoffman, D.J., G.J. Smith, and B.A. Rattner. 1993. Biomarkers of contaminant exposure in common terns and black crowned night herons in the Great Lakes. Great Lakes Environ. Toxicol. Chem. 12:1095 - 1103.

Hoffman, D. J., M. J. Melancon, P. N. Klein, J. D. Eisemann, and J. W. Spann. 1998. Comparative developmental toxicity of planar polychlorinated biphenyl congeners in chickens, American kestrels, and common terns. Environ. Toxicol. Chem. 17:747–757.

Hoogesteijn, A. L., T. J. DeVoogd, F. W. Quimby, T. De Caprio, and G. V. Kollias. 2005. Reproductive impairment in zebra finches (*Taeniopygia guttata*). Environ. Toxicol. Chem. 24:219–223.

Hughes, K., D. Crump, K. Williams, P. Martin. 2014. Assessment of the wildlife deformities and reproductive problems BUI: St. Marys River AOC. http://www.lssu.edu/bpac/wp-content/uploads/2014/05/EC-Assessment-of-Wildlife-Deformities-and-Reproduction-BUI-in-St.-Marys-River-AOC-Ontario-Feb-2014.pdf

Hughes, K.D., S. R. de Solla, K. J. Fernie, C. E. Hebert, P. A. Martin, T. V. McDaniel, J. L. Shutt, and D. V. C. Weseloh. 2010. Current status and trends of aquatic wildlife in the St. Lawrence River (Cornwall) Area of Concern. Final Report. 76 pp.

International Joint Commission (IJC). 1987. Revised Great Lakes Water Quality Agreement of 1978 as amended by protocol signed November 18, 1987. Accessed at:

http://www.ijc.org/files/tinymce/uploaded/GLWQA_e.pdfJohnson, D. R., W. E.

Melquist, and G. J. Schroeder. 1975. DDT and PCB levels in Lake Coeur d'Alene, Idaho, osprey eggs. Bull. Environ. Contam. Toxicol. 13:401–405.

Kannan, K., K. Hilscherova, T. Imagawa, N. Yamashita, L. Williams, J.P. Giesy. 2001. Polychlorinated Napthalenes, -Biphenyls, -Dibenzo-p-dioxins, and –Dibenzofurans in double-crested cormorants and herring gulls from Michigan waters of the Great Lakes. Environmental Science and Technology. 35:441-447.

Karwowski K. 1992. Biomonitoring and assessment of environmental contaminants in breeding common terns (*Sterna hirundo*) of the St. Lawrence River. Technical Report, Region 5. U.S. Fish and Wildlife Service: 9-12.

Kiff, L. F., D. B. Peakall, and S. R. Wilbur. 1979. Recent changes in California condor eggshells. Condor 81:166–172.

Kubiak, T.J., H.J. Harris, L.M. Smith, T.R. Schwartz, D.I. Stalling, J.A. Trick, L. Sileo, D.E. Docherty and T.C. Erdman. 1989. Microcontaminants and reproductive impairment of the Forster's tern on Green Bay, Lake Michigan - 1983. Arch. Environ. Contam. Toxicol. 18:706 - 727.

Lafrance, A., B. Tarbell, M. Arquette, and A. Cook. 2015. Personal communications. Akwesasne Cultural Restoration (ACR) Program, Saint Regis Mohawk Tribe Environment Division.

Lavoie, R. A., L. Champoux, J.F. Rail, D.R. Lean. 2010. Organochlorines, brominated flame retardants and mercury levels in six seabird species from the Gulf of St. Lawrence (Canada): relationships with feeding ecology, migration and molt. Environmental Pollution, 158(6), 2189-2199.

Martin, P.A., S.R. de Solla, and P. Ewins. 2003. Chlorinated hydrocarbon contamination in osprey eggs and nestlings from the Canadian Great Lakes Basin, 1991-1995. Ecotoxicology. 12:209-224.

Martinovic, B., C.A. Bishop, A. Secord, D. Lean, E. Birmingham, K. Jock, and J. Struger. Unpublished. Contaminant levels and reproductive success in tree swallows (*tachycineta bicolor*) nesting along the St. Lawrence River, Canada and USA. University of Ottawa, Department of Biology.

Martinovic, B., D.R. S. Lean, C.A. Bishop, E. Birmingham, A. Secord, and K. Jock. 2003a. Health of tree swallow (*Tachycineta bicolor)* nestlings exposed to chlorinated hydrocarbons in the St. Lawrence River basin. Part I. Renal and hepatic vitamin A concentrations. *J. Toxicol. Environ. Health. Part A*. 66:1053-1072.

Martinovic, B., D. Lean, C. Bishop, E. Birmingham, A. Secord, K. Jock. 2003b. Health of tree swallow (*Tachycineta bicolor*) nestlings exposed to chlorinated hydrocarbons in the St. Lawrence River Basin. Part II. Basal and stress plasma corticosterone concentrations. J. Toxicol. Environ. Health A. 66:2015-2029.

Mayer, M., L. Olendzenski, M. Skeels, and C. Cady. 2011. Assessment of mercury levels in wetland wildlife in the St. Lawrence River and the St. Lawrence River valley. Report to the St. Lawrence River Research and Education Fund of New York Power Authority. November 7, 2011. 11 pp.

McKenzie, Larry. 2008 Hotinonhsonni Social Songs and Dances Part 1-4. Retrieved February 22, 2016 from

Part 1: https://www.youtube.com/watch?v=6NnqxTv2_uM

Part 2: https://www.youtube.com/watch?v=aSGJse7q9uE

Part 3: https://www.youtube.com/watch?v=-wLKu__BW44

Part 4: https://www.youtube.com/watch?v=F0w3j_pQSNA

McKenzie, Larry. 2009. Hotinonhsonni Social Songs and Dances Part 5. Retrieved February 22, 2016 from

Part 5: https://www.youtube.com/watch?v=6a72Vh85dn8

McLane, M.A. and D.L. Hughes. 1980. Reproductive success of screech owls fed Aroclor 1248. Arch. Environ. Contam. Toxicol. 9: 661 - 665.

Meyer M.W., D.C. Evers, J.J. Hartigan, and P.S. Rasmussen. 1998. Patterns of common loon (*Gavia immer*) mercury exposure, reproduction, and survival in Wisconsin, USA. Environmental Toxicology and Chemistry. 17:184-90.

Mierzykowski, S. E. 2008. Environmental contaminants in tern eggs from Monomoy National Wildlife Refuge and Seal Island National Wildlife Refuge. USFWS Special Project Report FY07-MEFO-6-EC. Maine Field Office, Old Town ME. 27 pp.

Natural Resource Trustees of the St. Lawrence River Environment [National Oceanic and Atmospheric Administration (NOAA), New York State Department of Environmental Conservation (NYSDEC), St. Regis Mohawk Tribe Environment Division (SRMT), United States Fish and Wildlife Service (USFWS)]. 2013. St. Lawrence River Environment Natural Resource Damage Assessment: Restoration and compensation determination plan and environmental assessment. Appendix A of Consent Decree. March 2013.

New York State Department of Environmental Conservation (NYSDEC). 1981. Toxic substances in fish and wildlife 1979 and 1980. Annual Reports Volume 4-1. June 1981. Technical Report 81-1. 106 pp.

New York State Department of Environmental Conservation (NYSDEC). 1990. Natural resource damages preassessment screen for the St. Lawrence, Grasse, and Raquette rivers and environs, Massena, New York. September 1990. 185 pp.

New York State Department of Environmental Conservation (NYSDEC). 1999. List of endangered, threatened and special concern fish and wildlife species of New York State. http://www.dec.ny.gov/animals/7494.html

Newell, A.J., D.W. Johnson and L.K. Allen. 1987. Niagara River Biota Contamination Project: Fish Flesh Criteria for Piscivorous Wildlife. New York State Department of Environmental Protection, Division of Fish and Wildlife, Bureau of Environmental Protection, Tech. Repo. No. 87-3, 182 pp.

Nisbet, I. C. T. 1982. Eggshell characteristics and organochlorine residues in Common Terns: variation with egg sequence. Colonial Waterbirds 5:139-143

Nisbet, I. C. 2002. Common Tern (*Sterna hirundo*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/618

North American Indian Traveling College (NAITC). 1984. *Traditional Teachings*. Edited by Barbara Kawenehe Barnes. 101 pp.

North American Indian Traveling College (NAITC). 2007. *Words That Come Before All Else*. Environmental philosophies of the Haudenosaunee. Prepared by the Haudenosaunee Environmental Task Force. 161 pp.

Ogden, J.C., W.B. Robertson, Jr., G.E. Davis and T.W. Schmidt. 1974. Pesticides, polychlorinated biphenyl and heavy metals in upper food chain levels, Everglades National Park and vicinity. Final Report, Division of Natural Science and Resource Management Studies, Everglades National Park.

Peakall, D.B., and M.L. Peakall. 1973. Effects of a polychlorinated biphenyl on the reproduction of artificially and naturally incubated dove eggs. *J. Applied Ecology* 10:863-868.

Pekarik, C., D.V.C. Weseloh D.V.C. 1998. Organochlorine contaminants in herring gull eggs from the Great Lakes, 1974–1995: change point regression analysis and short-term regression. Environmental Monitoring and Assessment 53:77–115.

Pierotti, R. and C. A. Annett. 1991. Diet choice in the herring gull: constraints imposed by reproductive and ecological factors. Ecology 72(1):319-328.

Poole, A. F., R. O. Bierregaard and M. S. Martell. 2002. Osprey (*Pandion haliaetus*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/683

Rattner, B.A., P.C. McGowan, N.H. Golden, J. Hatfield, P.C. Toschik, R.F. Lukei, Jr., R.C. Hale, I. Schmitz-Afonso, and C.P. Rice. 2004. Contaminant exposure and reproductive success of ospreys (*Pandion haliaetus*) nesting in Chesapeake Bay regions of concern. Archives of Environmental Contamination and Toxicology 47:126-140.

Rattner, B.A., P.C. McGowan, N.H. Golden, J.S. Hatfield, P.C. Toschik, R.F. Lukei Jr, R.C. Hale, I. Schmitz-Afonso, C.P. Rice. 2004. Contaminant exposure and reproductive success of ospreys (*Pandion haliaetus*) nesting in Chesapeake Bay Regions of Concern. Archives of Environmental Contamination and Toxicology. 47:126-140.

Riveredge Associates. 2013. Quality Assurance Project Plan (QAPP) for field collection activities for avian habitat, populations, reproduction and contaminants in and adjacent to the Massena/Akwesasne Area of Concern. QAPP prepared and submitted to EPA.80 pp. Draft prepared March 31, 2013. Revised Final May 20, 2013.

Riveredge Associates. 2014 Lake St. Lawrence Common Tern Habitat Improvement Project: 2013 status assessment and colony enhancements. Report for the New York Power Authority by Riveredge Associates, Massena, New York. Draft Final Report, September 2014. 36 pp.

Skinner. L.C. 1992. Chemical contaminants in wildlife from the Mohawk Nation at Akwesasne and the vicinity of the General Motors Corporation/Central Foundry Division, Massena, New York. Technical Report 92-4 (BEP) Division of Fish and Wildlife, New York State Department of Environmental Conservation. 104pp.

Spitzer, P. R., R. W. Risebrough, W. Walker II, R. Hernandez, A. Poole, D. Puleston, and I. C. T. Nisbet. 1978. Productivity of ospreys in Connecticut-Long Island increases as DDE residues decline. Science 202:333–335.

Szaro, R.C., N.C. Coon, and E. Kolbe. 1979. Pesticide and PCB of common eider, herring gull, and great black-backed gull eggs. Bulletin of Environmental Contamination and Toxicology 22:394-399

Szczechowski, B., J. N. Bull, and E. Wilke. 2009. Detroit River-Western Lake Erie Basin Indicator Project; Indicator: Common tern reproduction. http://www.epa.gov/med/grosseile_site/indicators/common-terns.html

Saint Regis Mohawk Tribe (SRMT), Environment Division. 2014. Game advisory. GL-972296010. Available at: http://www.srmtenv.org/web_docs/WRP/2014/11/201411_game_advisory.pdf

Teeple, S.M. 1977. Reproductive success of herring gulls nesting on Brothers Island, Lake Ontario, in 1973. Canadian Field-Naturalist 91:148-156.

Tetra Tech. 2011. Fish and wildlife populations beneficial use impairment St. Lawrence River at Massena Area of Concern. Report prepared for USEPA Region 2 and GLNPO. November 2011. 235 pp.

Tillitt, D.E., G.T. Ankley, J.P. Giesy, J.P. Ludwig, H. Kurita-Matsuba, D.V. Weseloh, P.S. Ross, C.A. Bishop, L. Sileo, K.L. Stromberg, J. Larson, and T.J. Kubiak. 1992. Polychlorinated biphenyl residues and egg mortality in double-crested cormorants from the Great Lakes. Environ. Toxicol. Chem. 11: 1281 - 1288.

Toschik, P.C., B.A. Rattner, P.C. McGowan, M.C. Christman, D.B. Carter, R.C. Hale, C.W. Matson, and M.A. Ottinger. 2005. Effects of contaminant exposure on reproductive success of ospreys (*Pandion haliaetus*) nesting in Delaware River and Bay, USA. Environmental Toxicology and Chemistry. 24:617-628.

TRC. 1993. Draft risk assessment. Aluminum company of america (ALCOA) study area, Massena, New York. Prepared for U.S. Environmental Protection Agency. EPA Site ID NYD980506232.

USEPA. 1990. Decision Document. Record of Decision for General Motors OU 01 (Central Foundry Division). EPA ID: NYD091972554.

USEPA. 1993. Decision Document. Record of Decision for Reynolds Metals Company.

USEPA. 2002. Community culture and the environment: A guide to understanding a sense of place. EPA 842-B-01-003). Office of Water, Washington, DC. http://contextsensitivesolutions.org/content/reading/epa_community/resources/epa_com-cult-enviro/

USEPA. 2003. Ecological Risk Assessment for General Electric (GE)/Housatonic River Site, Rest of River, Vol. 6, Appendix H: assessment endpoint - Piscivorous birds. July 2003.

USEPA 2006. Data quality assessment: Statistical methods for practitioners (EPA QA/G-9S) http://www.epa.gov/quality

USEPA. 2008. Explanation of Significant Difference Reynolds Metals Company Site.

USEPA 2012a. Reynolds Metals Company Fact Sheet. EPA ID#: NYD002245967.

USEPA. 2012b. Grasse River Superfund Site Proposed Plan. September 2012. Massena, St. Lawrence County, New York.

USEPA. 2013a. Decision Document. Record of Decision for Grasse River Superfund Site.

USEPA. 2013b. Aluminum Company of America Fact Sheet. EPA ID#: NYD980506232. St. Lawrence, New York, NPL Listing History.

USEPA. 2013c. General Motors (Central Foundry Division) Fact Sheet. EPA ID#:NYD091972554. St. Lawrence, New York, NPL Listing History. Retrieved from website: http://www.epa.gov/r02earth/superfund/npl/gmmassena/index.html and http://www.epa.gov/region02/superfund/npl/0201644c.pdf

USEPA. 2013d. General Motors (Central Foundry Division) Fact Sheet. EPA ID#:NYD091972554. St. Lawrence, New York, NPL Listing History.

USEPA. 2015. Third five-year review report. General motors (central foundry division) superfund site. St. Lawrence County, Town of Massena, New York. Available at: http://semspub.epa.gov/work/02/372872.pdf

Vennesland, R. G. and R. W. Butler. 2011. Great Blue Heron (*Ardea herodias*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/025

Vos, J. G., H. L. van der Maas, A. Musch, and E. Tam. 1971. Toxicity of hexachlorobenzene in Japanese quail with special reference to porphyria, liver damage, reproduction, and tissue residues. Toxicol. Appl. Pharmacol. 18:944–957.

Weseloh D.V.C, C.A. Bishop, R.J. Norstrom, and G.A. Fox. 1991. Monitoring levels and effects of contaminants in herring gull eggs on the Great Lakes, 1974-1990. In: Abstracts from the papers given at the Cause-Effect Linkages II Symposium. September 27-28, 1991, pp 29-31. Lansing Michigan: Michigan Audubon Society

Weseloh, D.V.C., J. Rodrigue, H. Blokpoel, and P.J. Ewins. 1997. Contaminant concentrations in eggs of Black Terns (*Chlidonias niger*) from Southern Ontario and Southern Quebec, 1989-1996. Colonial Waterbirds. 20:604-616.

Weseloh, D. V., S. M. Teeple, and M. Gilbertson. 1983. Double-crested cormorants of the Great Lakes: egg-laying parameters, reproductive failure, and contaminant residues in eggs, Lake Huron 1972–1973. Can. J. Zool. 61:427–436.

Weseloh, D. V., T. W. Custer, and B. M. Braune. 1989. Organochlorine contaminants in eggs of Common Terns from the Canadian Great Lakes, 1981. Environ. Pollut. 59:141-160.

Weseloh, D.V.C., C. Pekarik, S. de Solla. 2006. Spatial patterns and rankings of contaminant concentrations in herring gull eggs from 15 sites in the Great Lakes and connecting channels, 1988–2002. Environmental Monitoring and Assessment 113:265–284.

Weseloh, D.V., D.J. Moore, C. E. Hebert, S R. de Solla, B. Braune, D. McGoldrick. 2011. Current concentrations and spatial and temporal trends in mercury in Great Lakes herring gull eggs, 1974-2009. Ecotoxicology. 20:1644-1658

Weseloh, D.V., P. Mineau, and J. Struger. 1990. Geographical distribution of contaminants and productivity measures of herring gulls in the Great Lakes: Lake Erie and connecting channels 1978/79. Science of the Total Environment 91:141-159.

Weseloh, D.V.C., P.J. Ewins, J. Struger, P. Mineau, and R. J. Norstrom. 1994. Geographical distribution of organochlorine contaminants and reproductive parameters in herring gulls on Lake Superior in 1983. Environmental Monitoring and Assessment 29:229-251

Wiemeyer, S.N., T.J. Lamont, C.M. Bunck, C.R. Sindelar, F.J. Gramlich, J.D. Fraser, and M.A. Byrd. 1984. Organochlorine pesticide, polychlorobiphenyl, and mercury residues in bald eagle eggs-1969-1979 – and their relationships to shell thinning and reproduction. Archives of Environmental Contamination and Toxicology 13: 529-549.

Wiemeyer, S. N., P. R. Spitzer, W. C. Krantz, T. G. Lamont, and E. Cromartie. 1975. Effects of environmental pollutants on Connecticut and Maryland ospreys. J. Wildl. Manage. 39:124–139.

Wiemeyer, S.N., C.M. Bunck, and A.J. Krynitsky. 1988. Organochlorine pesticides, polychlorinated biphenyls, and mercury in osprey eggs-1970-79-and their relationships to shell thinning and productivity. Archives of Environmental Contamination and Toxicology 17:767-787.

Woodford, J. E., W. H. Karasov, M. W. Meyer, and L. Chambers. 1998. Impact of 2,3,7,8-TCDD exposure on survival, growth, and behavior of ospreys breeding in Wisconsin, USA. Environ. Toxicol. Chem. 17:1323–1331.