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Early Detection and Monitoring of Non-Native Fishes in Lake Erie, 2017

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1 Executive Summary

The Laurentian Great Lakes have encountered numerous aquatic non-native and invasive species introductions since Europeans settled in North America (Mills et al. 1994). The impact of aquatic invasive species (AIS) on the Great Lakes has been widely documented by the scientific community (Leung et al. 2002; Mills et al. 1993; Rosaen et al. 2012). Despite increasing regulations aimed at reducing the likelihood of the introduction and spread of AIS into the Great Lakes, there remains a need to monitor for and detect new species before they become established. This is especially true given the costs and difficulty of attempting to control or eradicate a non-native species once it is established (Trebitz et al. 2009). If a non-native species is detected prior to becoming well established, rapid response decisions can be made in an effort to eradicate or control the species from further spread. Furthermore, continuous monitoring also allows resource managers to document the baseline community, look at historical data, and assess the impact of future invasions (Trebitz et al. 2009).

This report summarizes the 2017 efforts for early detection of non-native fishes in Lake Erie as implemented by the U.S. Fish and Wildlife Service (USFWS), Alpena Fish and Wildlife Conservation Office and the Lower Great Lakes Fish and Wildlife Conservation Office. Multiple sampling locations in Lake Erie were selected due to their high likelihood of new non-native species introductions as suggested by a risk based vector analysis completed as part of a regional surveillance plan for the U.S. waters of the Laurentian Great Lakes (Chadderton et al. 2016). Lake Erie sampling locations included Buffalo/upper Niagara (NY), Presque Isle Bay (PA), Cleveland Harbor (OH), Sandusky Bay (OH), Maumee Bay (OH/MI), and Lake St. Clair (MI). Sample sites were both randomly selected and also chosen by biologists while in the field (USFWS 2016a). Gear used to target juvenile and adult fish at the locations sampled included day/night electrofishing, gill nets, juvenile seine, minnow traps, bottom trawling, and paired fyke nets.

During adult/juvenile fish monitoring efforts conducted in 2017, surveillance crews captured a total of 8,121 fish representing 51 species in Buffalo/upper Niagara, a total of 5,603 fish representing 36 species in Presque Isle Bay, a total of 2,927 fish representing 34 species in Cleveland Harbor, a total of 12,393 fish representing 35 species in Maumee Bay, a total of 4,971 fish representing 24 species in Sandusky Bay, and a total of 4,248 fish representing 25 species in Lake St. Clair. Previously established invasive species were captured often during sampling (e.g., Alewife *Alosa pseudoharengus*, Common Carp *Cyprinus carpio*, Goldfish *Carassius auratus*, Rainbow Smelt *Osmerus mordax*, Round Goby *Neogobius melanostomus*, and White Perch *Morone americana*).

In 2017, no new non-native species were detected in the Lake Erie sampling locations. However, the threat of invasion remains high, such as the observed range expansion of Asian Carp *Hypophthalmichthys Spp.* in the Chicago Area Waterway System. This reinforces the critical nature of an annual early detection and monitoring program as an essential part of non-native and invasive species management for Lake Erie.

2 Introduction

Establishment of aquatic non-native species in the Great Lakes has caused major ecological and economic impacts (Mills et al. 1993; Vanderploeg et al. 2002; Rosaen et al. 2012; Rothlisberger et al. 2012). The cost of aquatic non-native species to the Great Lakes Region, whose fishery is valued at $7 billion (ASA 2008), is well over $100 million annually (Rosaen et al. 2012). An estimated $138 million is spent each year mitigating the damages generated by ship-borne non-native species, a single introduction vector representing only a portion of invasive species present in the Great Lakes (Rothlisberger et al. 2012). Non-native species have entered the Great Lakes through a variety of vectors including ballast water from shipping vessels, canals, aquarium releases, bait release, and intentional stocking by management agencies (Mills et al. 1994). The Great Lakes currently contain at least 182 identified nonindigenous aquatic species (Ricciardi 2006), 126 of which are present in the Lake Erie watershed (Great Lakes Aquatic Nonindigenous Species Information System, GLANSIS, NOAA 2016).

The impacts of historical non-native introductions in Lake Erie have been widely documented. Sea Lamprey

Petromyzon marinus presumably entered Lake Erie and spread to the upper Great Lakes by means of the Welland Canal (Aron and Smith 1971). Ecological and economic impacts from the lamprey invasion have been observed as losses in commercial and recreational fishing income, tourism, and costs associated with control measures (Smith and Tibbles 1980; Jones 2007). The United States and Canada spend over $20 million per year on sea lamprey control measures alone (Dissanayake et al. 2016). Zebra mussels *Dreissena polymorpha* and quagga mussels *D. bugensis* have altered trophic dynamics by competing for resources with native bivalves, promoting conditions favorable to harmful algal blooms, and concentrating energy resources into benthos causing oligotrophication (Vanderploeg et al. 2002). Additionally, these mussels negatively impact industries such as power plants and water treatment facilities (Lovell et al. 2006). Total economic costs of zebra mussels are estimated around $5 billion (Lovell et al. 2006). The introduction of Rainbow Smelt *Osmerus mordax* has caused declines in recruitment of native planktivores such as Lake Whitefish *Coregonus clupeaformis* and Lake Herring *Coregonus artedi* (Evans and Loftus 1987), and the subsequent spread of Alewife *Alsoa pseudoharengus* has been linked to reproductive failures in Lake Trout *Salvelinus namaycush* and Atlantic Salmon *Salmo salar* (Fisher et al. 1996).

Great Lakes waterways continue to face the threat of new invasions. Some non-native species have been documented as present but are not yet abundant, while others are not present but pose a high risk of invasion. Currently, the most notable potential invaders of the Great Lakes basin are four infamous species of Asian Carp: Bighead Carp *Hypophthalmichthys nobilis*, Silver Carp *Hypophthalmichthys molitrix*, Grass Carp *Ctenopharyngodon idella*, and Black Carp *Mylopharyngodon piceus*. Bighead and Silver Carp are large, planktivorous fish that have been reported to dominate fish assemblages (represent as much as 97% of total fish biomass in portions of the Mississippi River basin; MICRA 2002) and alter the structure and species composition of native plankton communities (Laws and Weisburd 1990; Vörös et al. 1997; Stone et al. 2000). Grass Carp have been captured at isolated locations within Lake Erie but are not known to be abundant (Baerwaldt et al. 2013; USGS 2017). Nonetheless, natural reproduction of Grass Carp has recently been documented within the Lake Erie watershed (Chapman et al. 2013; Embke et al. 2016). This species feeds on submerged aquatic macrophytes and may threaten coastal wetlands which are important spawning and rearing habitats for many species (Chapman et al. 2013). There have been isolated catches of adult Bighead Carp in Lake Erie including two captures near Sandusky in Ottawa County, Ohio in 1995 and 2000, and a capture west of Point Pelee in Ontario, Canada in 2000 (Morrison et al. 2004). However, there has been no evidence of establishment. Bighead and Silver Carp are known to inhabit rivers that indirectly connect to Lake Erie tributaries during high water events (GLMRIS 2011). Populations of Silver Carp and Bighead Carp have rapidly expanded in the Mississippi River and the Illinois River and are moving closer towards Lake Michigan and the Great Lakes (Chick and Pegg 2001). In the attempt to protect the ecological and economic value of the Great Lakes region, federal and state agencies plan to spend over $25 million in Asian Carp prevention and research annually (ACRCC 2016). Asian Carp represent just a few of the potential invaders threatening the Great Lakes resulting in costly prevention measures. Furthermore, many additional species have been identified as posing a high risk of introduction through ballast water, the aquarium trade, and other vectors outside of immediately connected waterways (Kolar and Lodge 2002; GLANSIS Watchlist, NOAA 2016). Minimizing additional introductions of non-native species to the Great Lakes has become increasingly important given the significant impacts existing invaders have had on this ecosystem.

The Great Lakes Restoration Initiative (GLRI 2014) is aimed at restoring and protecting the integrity of the Great Lakes and was first implemented in 2010. GLRI is a plan of action that recognizes regulation and education alone are not enough to protect and restore the Great Lakes. GLRI includes a number of focus areas that address Great Lakes issues including an Invasive Species component. Within the GLRI Invasive Species component there is a charge to "conduct early detection and monitoring activities". Preventing the transfer of a new species to an ecosystem is ultimately the most effective tool to keep non-native species from becoming invasive. When complete prevention is not possible, the next most effective option is monitoring for the arrival of new species and controlling their spread before they become widespread (USEPA 2008; Trebitz et al. 2009, Hoffman et al. 2016). In 2012 the Great Lakes Water Quality Agreement (1987) was renewed and included a number of annexes to address issues in the Great Lakes. One such is Annex 6, an Aquatic Invasive Species Annex whose purpose is to *"..establish a binational strategy to prevent the introduction of Aquatic Invasive Species (AIS), to control or reduce the spread of existing AIS, and to eradicate, where feasible, existing AIS within the Great Lakes Basin Ecosystem"*. Included in the Programs

and Measures component of the Annex is the task to develop and implement an early detection and rapid response initiative that: (a) develops species watch lists; (b) identifies priority locations for surveillance; (c) develops monitoring protocols for surveillance. Within the science efforts charged by the Annex is the need for *"development and evaluation of technology and methods, including genetic techniques, that improve the ability to detect potential AIS at low levels of abundance"*.

The U.S. Fish and Wildlife Service (USFWS) developed a strategic framework for the early detection of non-native fishes and select benthic macroinvertebrates in the Great Lakes (USFWS 2014b). Fish and Wildlife Conservation Offices (FWCOs) throughout the Great Lakes lead and coordinate this program. This report describes the efforts devoted to the early detection of non-native juvenile and adult fishes at multiple high risk locations in the Lake Erie basin in 2017, and is a continuation of coordinated efforts initiated in 2013.

3 Study Areas

Lake Erie study areas were chosen through the use of a vector risk analysis for species at risk to become introduced into the Great Lakes (Chadderton et al. 2016). Study areas, sampling gears, and sampling targets were identified in the *Lake Erie Implementation Plan for the Early Detection of Non-Native Fishes and Select Benthic Macroinvertebrates* (USFWS 2016a). Six study areas were sampled in 2017 including Buffalo/upper Niagara, Presque Isle Bay, Cleveland Harbor, Sandusky Bay, Maumee Bay, and Lake St. Clair (Figure 1). Three of these locations have been sampled annually 2013 - present, Buffalo/upper Niagara, Sandusky Bay, and Maumee Bay. Three locations were added to the sampling regime in 2017 based on a review of risk; Presque Isle Bay, Clevedand Harbor, and Lake St. Clair.

3.1 Buffalo/upper Niagara

Buffalo, New York and its surrounding waterways are industrialized areas that have historically been important to shipping within the Great Lakes. While commercial shipping traffic has declined over the past few decades, Buffalo remains the second-largest city in New York State and continues to see a large amount of tourism, recreational boating, and recreational fishing. Both the Buffalo and Niagara rivers were named Areas of Concern (AOCs) as part of the Great Lakes Water Quality Agreement of 1987. The upper Niagara River is defined as the portion of river above Niagara Falls. The Erie Canal, a known vector for invasive species, connects to the Great Lakes in the upper Niagara River, increasing this area's vulnerability to invasion. The aquatic habitat varies considerably within the survey area. The harbor consists of dredged channels with soft substrate, often with large expanses of submerged vegetation. Submerged riprap and/or sheet pilings dominate the shoreline within the harbor. The upper Niagara River consists of clear water with considerable flow in most locations and the substrate is dominated by a combination of clay and cobble, with submerged vegetation. The open lake area outside of the harbor and south to the westernmost shoreline boundary consists of mainly clear water with medium to large cobble/hard substrate interspersed with *Dreissena spp.* colonies. The study area was located within US waters in the easternmost part of Lake Erie at Buffalo and encompassed the Small Boat Harbor, south along approximately 16 km of shoreline, north to the Canadian border, as well as all New York waters of the upper Niagara River to Buckhorn Island. The total surface area of the survey location was approximately 21,560 ha.

3.2 Presque Isle Bay

Presque Isle Bay is located in Erie, Pennsylvania on the southern shore of Lake Erie at the eastern end of the central basin. Presque Isle Bay was listed as an AOC as part of the Great Lakes Water Quality Agreement of 1987 due to pollution from sewage and industrial waste, but was removed from the list in 2013 due to the success of remediation activities. The Presque Isle Bay embayment has a surface area of 1479 hectares, is 7.4 km in length, 2.9 km at its widest point, and has an average depth of 4 m. The natural bay is formed and

sheltered by a recurved peninsula that makes up Presque Isle State Park, a National Natural Landmark that attracts over four million visitors a year to recreate via swimming, boating, fishing, biking, and bird watching. The bay is bounded by Presque Isle on the west and north ends, and the easterly end of the bay has been dredged to create Erie Harbor connecting to Lake Erie via a shipping channel maintained by the Army Corps of Engineers. The bay shoreline is characterized by numerous small bays, coves, and inlets. Erie is Pennsylvania's primary access point to Great Lakes shipping routes, which caused the area to become a hub of heavy manufacturing industries. While total ballast discharged in the bay is low, it has a high proportion of ballast water sourced from overseas which increases the risk of a non-native species introduction (NBIC 2016). Two main tributaries of Presque Isle Bay, Mill Creek and Cascade Creek, account for two-thirds of the bay's water supply.

3.3 Cleveland Harbor

Cleveland Harbor is located at the mouth of the Cuyahoga River, a tributary to Lake Erie, in the city of Cleveland, Ohio. The Cuyahoga River runs through downtown Cleveland, a densely populated area with a high amount of recreational angling and boating. The Cuyahoga River is also a major bulk freight shipping port for the Great Lakes and the surrounding area is highly industrialized. The Cuyahoga River was designated an AOC as part of the Great Lakes Water Quality Agreement of 1987 due to industrial pollution, sewage and debris resulting in a number of beneficial use impairments. The study area was located within and around the seawall surrounding Cleveland Harbor. The total surface area of the sampling location was approximately 3,540 ha.

3.4 Sandusky Bay

Sandusky Bay is located in northern Ohio on Lake Erie near the cities of Sandusky and Port Clinton. The bay is shallow and fed by the Sandusky River. A hydrologic connection between the Mississippi River basin and the Sandusky River via Grand Lake and the St. Mary's River makes this a high-risk pathway for introductions of non-native species to Lake Erie (GLMRIS 2011). Sandusky maintains a port for maritime commerce. The study area encompassed the eastern boundary of Muddy Creek Bay at Peach Island and Canvasback Point, and extended east approximately 24 km to the easternmost boundary of Cedar Point. The total surface area of the survey location was approximately 13,500 ha.

3.5 Maumee Bay

Maumee Bay is located in the southwest corner of Lake Erie's western basin near the city of Toledo, Ohio, and includes both Michigan and Ohio waters of Lake Erie. Toledo, the fourth largest city in Ohio, is a major commercial shipping port receiving high levels of ballast water. Maumee Bay supports tourism, including recreational boating and fishing. The Maumee River, the largest tributary to Lake Erie, was named an AOC as part of the Great Lakes Water Quality Agreement of 1987 due to sediment contamination and agricultural runoff. The Maumee River originates at the confluence of the St. Joseph and St. Mary's rivers near Fort Wayne, Indiana, and represents a potential pathway for non-native species to enter Lake Erie from the Mississippi River basin via Eagle Marsh (GLMRIS 2011). In an effort to help prevent the spread of non-native species between these basins, a berm was constructed at Eagle Marsh in 2015. The study area encompassed the Maumee River approximately 1 km upstream from the river mouth, and into Maumee Bay northeast approximately 26 km to a parallel boundary extending north from the outer boundary of Cedar Point National Wildlife Refuge northwest to Grand View, Michigan. Maumee Bay waters within Michigan and Ohio were within the study area, and the total surface area of the survey location was approximately 9,200 ha.

3.6 Lake St. Clair

Lake St. Clair is the middle part of a connecting channel between Lakes Huron and Erie and serves as the international boundary between the United States (Michigan) and Canada (Ontario). Water enters Lake St. Clair at the north via the St. Clair River and leaves at the south via the Detroit River which drains into Lake Erie. This combined waterway is included as part of the Lake Erie watershed by the Great Lakes Fishery Commission, and forms an important navigational shipping route connecting lakes Michigan, Huron, and Superior (the upper Great Lakes) with lakes Erie and Ontario (the lower Great Lakes) and the St. Lawrence Seaway. Recreational fishing and boating are popular on Lake St. Clair. The area consists of residential housing with a number of marinas. The lake is shallow averaging 3.4 m in water depth and has a marsh complex that is valuable habitat for fish, birds, and wildlife. The study area encompassed U.S. waters in Michigan and the total surface area of the sampling location was approximately 15,830 ha.

4 Methods

4.1 Adult/Juvenile Fish Sampling

Adult and juvenile fish were targeted using diverse sampling gears deployed at a range of water depths in an attempt to collect as many species present in the fish community as possible. Although not reported in this document, catch results from the different gear types are used to determine which gears collect a greater number of unique species and is used to inform future sampling efforts. Sampling gears used to target adult and juvenile fish included paired fyke nets, boat electrofishing, juvenile seine nets, micro-mesh gill nets, minnow traps, and benthic trawling.

Paired fyke nets consisted of two 0.91 m x 1.22 m fyke nets constructed of 4.69 mm (3/16" delta) stretch mesh netting that were attached together with a 15 m x 0.91 m lead resulting in a paired net. Each individual net consisted of two rectangular frames 0.91 m x 1.22 m, followed by four circular rings 0.91 m in diameter. Paired fyke nets were set parallel to the shoreline or in “weed pockets” in water depths of 1.0-4.4 m. Nets were set during the daytime, and remained in the water overnight and retrieved the following day during daylight hours. Nets were deployed for no longer than 30 hours, with a typical set time ranging from 12-30 hours. Effort was measured in overnight sets.

Boat electrofishing was conducted during day and night hours, in water depths of 1.0-3.0 m. A pulsed DC current 60 Hz electrical unit with sufficient power to induce taxis in fish. The electrofishing power was dependent upon water conductivity and the level of boat-hull oxidation. A Smith Root control box was used to generate electrical impulses used during day electrofishing and a midwest Lake Electrofishing system control box was used during night electrofishing. Electrofishing was conducted along one 600 s transect near each predetermined waypoint. Effort was converted to hours fished.

Juvenile seine nets consisted of two 1.52 m wooden poles connected by 5 mm rectangular mesh net measuring 7.32 m by 1.22 m with a 1.37 m deep mesh bag in the center. Seine hauls were conducted in areas in which underwater terrain was condusive. Hauls were typically no shorter than 50 m long and ended by dragging the net onto the shoreline. Effort is per each seine net haul.

Micro-mesh gill nets were 9.14 m x 1.83 m consisting of three 3.05m x 1.83m panels of 9.53 mm, 12.7 mm, and 15.88 mm square mesh. The nets were held between a floating and weighted lead that were attached on either end to a rope lead which was attached to an anchor and ball buoy on each side. Gill nets were placed on the bottom of the water column, with the remainder of the net extending upwards. Gill nets were deployed for 3 hours and effort is per each gill net set.

Gee’s minnow traps were 42 mm x 23 mm of conical design and constructed of 0.6 mm galvanized steel mesh. Each end had a 25.4 mm funnel shaped entrance to the trap. Traps were baited and set on the bottom in an array of 5 traps per line. Traps were set overnight for a period of 12-24 hours. Effort was measured in overnight sets.

Bottom trawls were Marinovich design and consisted of a trawl with a 4.9 m head rope, 3.8 cm stretch mesh body, and a 3.125 mm stretch mesh cod end. Trawl tows were performed on contour for five or ten minutes at a speed of approximately 4 km/h, and at depths greater than 2 m. Trawls were recovered using a hydraulic winch or by hand. Effort was converted to hours fished. Bottom trawls were conducted where conducive on even substrate and soft material, not in areas with rocky or uneven substrate or at locations with swift water currents, and therefore could not be conducted in the lower Niagara River or Irondequoit Bay due to factors listed above. Effort was reported as fish per minute.

ArcGIS 10.2 was used to select sampling sites across water depth strata (<2 m, 1-2 m, and > 2 m) present in each study area according to a stratified randomized design. Study areas were predefined using polygon shapefiles in ArcGIS. A bathymetry data layer was used to define depth strata within the polygon. Random points, corresponding to GIS coordinates, were selected within each depth strata using the Create Random Points function in ArcGIS 10.2. Due to lack of available bathymetric data for many of the areas to be sampled (shallow, near shore, outside of dredged areas), shape files were modified for estimated depth ranges corresponding to gear types. Some sites were also selected by biologists while in the field based on previously defined diversity "hotspots". The Hot Spot Analysis (Getis-Ord Gi*) tool within ArcGIS 10.4 was used to statistically identify species richness clusters in all sampling locations to determine areas of proportionally high species richness in which to sample within (Ord and Getis 1995).

Gears used during this study and the amount of effort deployed was based on recommendations from Trebitz et al. (2009) and USFWS (2014a). When a randomly selected point was unable to be sampled (e.g. wrong depth, inaccessibility), an alternate site was selected from a list of previously allocated randomized alternate locations (<50% of sampling site selections).

4.2 Species Accumulation and Extrapolated Richness

Species accumulation models describe the cumulative number of species recorded in a particular environment as a function of the cumulative search effort. While these models describe the rate at which species have been observed, they do not describe the total number of species that may have been missed. To estimate total species richness we used incidence-based functions that assume the number of not captured species is related to the number of rare species. Singletons (species detected once) and doubletons (species detected twice) identify rare species and contribute to rarefaction analysis as they can affect the number of predicted species (if there are many singletons and/or doubletons the amount of species predicted will increase). The Chao estimator assumes the number of missed species is related to the proportional difference between singletons (f_1) and doubletons (f_2) within the reference sample (sampling event, n):

$$S_C = S_{Obs} + \frac{f_1^2}{2f_2}\left(\frac{n-1}{n}\right)$$

Sample-based rarefaction and extrapolation were conducted and species accumulation curves were calculated using the Chao asymptotic richness estimator in the package "iNEXT" with R statistical software (Chao et al. 2014; Hsieh et al. 2016; R Core Team 2016) and species abundance data (randomized pooling of data) from 2012-2017 for 300 sample extrapolations at 100 replications. The methods used followed Chao et al. (2009). Estimated species richness is the asymptote of the extrapolated rarefaction curve.

Catch per unit effort was determined for all fish species captured in 2017. All statistical analyses found within this report were performed using the computing environment R (R Core Team 2016).

5 Results

5.1 Buffalo/upper Niagara

A total of 8,121 fish representing 51 species were collected between May 30, 2017 and November 14, 2017 (Table 1, Figure 2). No undocumented non-native species were identified; however, 10 existing non-native species were detected and are denoted within the catch summary.

A total of 3,227 fish representing 41 species were collected following 40 electrofishing transects sampled between August 08, 2017 and November 14, 2017 at surface water temperatures between 10.1 and 25.4° C. The two species that comprised the largest percentages of the total catch were; Yellow Perch (13.9%) and Bluntnose Minnow (12%). Notable species from the remainder of the catch was composed of White Sucker (10.5%), Rainbow Smelt (8.9%), and Spottail Shiner (7.8%).

A total of 3,320 fish representing 32 species were collected as a result of 12 paired fyke net sets sampled overnight between August 03, 2017 and August 23, 2017 at surface water temperatures between 22.3 and 25.6° C. The two species that comprised the largest percentages of the total catch were; Bluntnose Minnow (41.7%) and Bluegill (11.2%). Notable species from the remainder of the catch was composed of Largemouth Bass (9.8%), Alewife (9.7%), and Rock Bass (6.7%).

A total of 978 fish representing 23 species were collected as a result of 10 juvenile seine net hauls sampled between August 02, 2017 and August 24, 2017 at surface water temperatures between 21.4 and 27.5° C. The two species that comprised the largest percentages of the total catch were; Emerald Shiner (28.4%) and Brook Silverside (17.1%). Notable species from the remainder of the catch was composed of Bluegill (12.1%), Brown Bullhead (9.9%), and Bluntnose Minnow (6%).

A total of 56 fish representing 8 species were collected using 8 micro-mesh gill net sets sampled between June 14, 2017 and September 11, 2017 at surface water temperatures between 18.6 and 25° C. The two species that comprised the largest percentages of the total catch were; Spottail Shiner (32.1%) and Gizzard Shad (28.6%). Notable species from the remainder of the catch was composed of Yellow Perch (19.6%), Round Goby (7.1%), and Logperch (5.4%).

A total of 540 fish representing 19 species were collected following 9 bottom trawl tows sampled between May 30, 2017 and October 25, 2017 at surface water temperatures between 14.5 and 19.3° C. The two species that comprised the largest percentages of the total catch were; Round Goby (69.4%) and Yellow Perch (21.1%). Notable species from the remainder of the catch was composed of Spottail Shiner (2.2%), White Sucker (1.7%), and White Perch (1.5%).

5.2 Presque Isle Bay

A total of 5,603 fish representing 36 species were collected between May 24, 2017 and November 07, 2017 (Table 2, Figure 3). No undocumented non-native species were identified; however, 7 existing non-native species were detected and are denoted within the catch summary.

A total of 1,520 fish representing 28 species were collected following 16 electrofishing transects sampled between October 17, 2017 and October 18, 2017 at surface water temperatures between 14.6 and 17.9° C. The two species that comprised the largest percentages of the total catch were; Yellow Perch (40.6%) and Gizzard Shad (10.9%). Notable species from the remainder of the catch was composed of Bluegill (8.9%), Largemouth Bass (8.4%), and Mimic Shiner (7%).

A total of 1,881 fish representing 19 species were collected as a result of 12 paired fyke net sets sampled overnight between October 16, 2017 and October 18, 2017 at surface water temperatures between 16.2 and 18.3° C. The two species that comprised the largest percentages of the total catch were; Bluegill (64.7%) and Round Goby (8.1%). Notable species from the remainder of the catch was composed of Pumpkinseed (7.7%), Yellow Perch (6.8%), and Black Crappie (4.1%).

A total of 1,037 fish representing 8 species were collected as a result of 4 juvenile seine net hauls sampled between October 17, 2017 and October 18, 2017 at surface water temperatures between 16.7 and 17.5° C. The two species that comprised the largest percentages of the total catch were; Brook Silverside (64.9%) and Mimic Shiner (19.9%). Notable species from the remainder of the catch was composed of Banded Killifish (9.5%), Emerald Shiner (4.8%), and Bluntnose Minnow (0.5%).

A total of 373 fish representing 9 species were collected following 6 micro-mesh gill net sets sampled between October 17, 2017 and October 18, 2017 at surface water temperatures between 16.2 and 17.9° C. The two species that comprised the largest percentages of the total catch were; Yellow Perch (33.5%) and White Perch (28.7%). Notable species from the remainder of the catch was composed of Alewife (22.8%), Gizzard Shad (7.2%), and Spottail Shiner (4.8%).

A total of 792 fish representing 15 species were collected using 8 bottom trawl tows sampled between May 24, 2017 and November 07, 2017 at surface water temperatures between 11.1 and 16.4° C. The two species that comprised the largest percentages of the total catch were; Yellow Perch (79.2%) and Round Goby (8.2%). Notable species from the remainder of the catch was composed of White Perch (2.4%), Trout-Perch (2.1%), and Bluegill (1.8%).

5.3 Cleveland Harbor

A total of 2,927 fish representing 34 species were collected between May 12, 2017 and November 08, 2017 (Table 3, Figure 4). No undocumented non-native species were identified; however, 7 existing non-native species were detected and are denoted within the catch summary.

A total of 735 fish representing 26 species were collected using 20 electrofishing transects sampled between September 19, 2017 and September 20, 2017 at surface water temperatures between 21.1 and 23° C. The two species that comprised the largest percentages of the total catch were; Yellow Perch (21.5%) and Emerald Shiner (11.7%). Notable species from the remainder of the catch was composed of Rock Bass (10.9%), Smallmouth Bass (10.9%), and Largemouth Bass (10.6%).

A total of 1,377 fish representing 15 species were collected as a result of 10 paired fyke net sets sampled overnight between September 19, 2017 and September 21, 2017 at surface water temperatures between 21 and 23.3° C. The two species that comprised the largest percentages of the total catch were; Bluegill (76.8%) and Rock Bass (8.4%). Notable species from the remainder of the catch was composed of Yellow Perch (6.5%), Round Goby (3.6%), and Yellow Bullhead (2.5%).

A total of 35 fish representing 5 species were collected as a result of 10 minnow trap net sets sampled overnight between September 20, 2017 and September 21, 2017 at surface water temperatures between 20.4 and 24.2° C. The two species that comprised the largest percentages of the total catch were; Round Goby (42.9%) and Spottail Shiner (31.4%). Notable species from the remainder of the catch was composed of Bluegill (14.3%), White Perch (8.6%), and Channel Catfish (2.9%).

A total of 501 fish representing 9 species were collected using 15 micro-mesh gill net sets sampled between September 18, 2017 and September 21, 2017 at surface water temperatures between 20.6 and 22.6° C. The two species that comprised the largest percentages of the total catch were; White Perch (72.5%) and Yellow Perch (21.2%). Notable species from the remainder of the catch was composed of Gizzard Shad (2.4%), Emerald Shiner (2.2%), and Spottail Shiner (0.8%).

A total of 279 fish representing 13 species were collected using 10 bottom trawl tows sampled between May 12, 2017 and November 08, 2017 at surface water temperatures between 12 and 14° C. The two species that comprised the largest percentages of the total catch were; Mimic Shiner (36.6%) and Round Goby (16.5%). Notable species from the remainder of the catch was composed of Gizzard Shad (12.2%), Emerald Shiner (10.4%), and Yellow Perch (10.4%).

5.4 Sandusky Bay

A total of 4,971 fish representing 24 species were collected between August 08, 2017 and August 30, 2017 (Table 4, Figure 5). No undocumented non-native species were identified; however, 6 existing non-native species were detected and are denoted within the catch summary.

A total of 209 fish representing 8 species were collected using 15 electrofishing transects sampled between August 08, 2017 and August 11, 2017 at surface water temperatures between 22.8 and 25.3° C. The two species that comprised the largest percentages of the total catch were; Gizzard Shad (81.3%) and Brook Silverside (12.4%). Notable species from the remainder of the catch was composed of Emerald Shiner (1.9%), Walleye (1.4%), and Freshwater Drum (1%).

A total of 1,667 fish representing 20 species were collected as a result of 15 paired fyke net sets sampled overnight between August 29, 2017 and August 30, 2017 at surface water temperatures between 21.7 and 22.9° C. The two species that comprised the largest percentages of the total catch were; White Perch (63.9%) and Gizzard Shad (7.4%). Notable species from the remainder of the catch was composed of Freshwater Drum (6.4%), Round Goby (5.5%), and Yellow Perch (3.5%).

A total of 3,095 fish representing 12 species were collected using 15 bottom trawl tows sampled between August 28, 2017 and August 30, 2017 at surface water temperatures between 22.3 and 23.3° C. The two species that comprised the largest percentages of the total catch were; Rainbow Smelt (58.8%) and White Perch (19.6%). Notable species from the remainder of the catch was composed of Gizzard Shad (15.4%), Mimic Shiner (3.4%), and Freshwater Drum (1.4%).

5.5 Maumee Bay

A total of 12,393 fish representing 35 species were collected between August 15, 2017 and September 27, 2017 (Table 5, Figure 6). No undocumented non-native species were identified; however, 4 existing non-native species were detected and are denoted within the catch summary.

A total of 683 fish representing 23 species were collected using 20 electrofishing transects sampled between September 11, 2017 and September 15, 2017 at surface water temperatures between 19.1 and 21.7° C. The two species that comprised the largest percentages of the total catch were; Gizzard Shad (55.8%) and Yellow Perch (12.6%). Notable species from the remainder of the catch was composed of Brook Silverside (6.7%), Emerald Shiner (6%), and Brown Bullhead (4.5%).

A total of 3,981 fish representing 27 species were collected as a result of 20 paired fyke net sets sampled overnight between August 15, 2017 and September 26, 2017 at surface water temperatures between 23.3 and 26.4° C. The two species that comprised the largest percentages of the total catch were; Bluegill (59.9%) and Spottail Shiner (10.8%). Notable species from the remainder of the catch was composed of Round Goby (7.2%), White Perch (6.4%), and Yellow Perch (3.8%).

A total of 7,729 fish representing 18 species were collected using 20 bottom trawl tows sampled between August 15, 2017 and September 27, 2017 at surface water temperatures between 22.4 and 25.4° C. The two species that comprised the largest percentages of the total catch were; White Perch (54.4%) and Mimic Shiner (23.9%). Notable species from the remainder of the catch was composed of Channel Catfish (6.5%), Yellow Perch (6.2%), and Gizzard Shad (5.2%).

5.6 Lake St. Clair

A total of 4,248 fish representing 25 species were collected between October 02, 2017 and November 08, 2017 (Table 6, Figure 7). No undocumented non-native species were identified; however, 3 existing non-native species were detected and are denoted within the catch summary.

A total of 2,501 fish representing 18 species were collected as a result of 15 paired fyke net sets sampled overnight between October 03, 2017 and November 08, 2017 at surface water temperatures between 9.1 and

20.3° C. The two species that comprised the largest percentages of the total catch were; Rock Bass (27.4%) and Yellow Perch (24.3%). Notable species from the remainder of the catch was composed of Bluegill (20.8%), Round Goby (20.5%), and Smallmouth Bass (2.3%).

A total of 1,747 fish representing 18 species were collected using 15 bottom trawl tows sampled between October 02, 2017 and October 05, 2017 at surface water temperatures between 18.4 and 22.2° C. The two species that comprised the largest percentages of the total catch were; Yellow Perch (87.8%) and Rock Bass (3.9%). Notable species from the remainder of the catch was composed of Round Goby (2.6%), Logperch (1.9%), and Spottail Shiner (1.1%).

5.7 Species Accumulation and Extrapolated Richness

Rarefaction Curves for juvenile and adult fish sampling were generated for all Lake Erie sampling locations based on data collected from 2013 to 2017, excluding Cleveland Harbor, Presque Isle Bay, and Lake St. Clair which were sampled beginning in 2017.

Buffalo/upper Niagara - An estimated 82.95 species are present as a result of 2013-2017 data analysis; while 71 species were captured using all sampling gears (Figure 8). A total of 260 sites have been sampled since the beginning of surveillance at this location.

Presque Isle Bay - An estimated 46.88 species are present as a result of 2016-2017 data analysis; while 38 species were captured using all sampling gears (Figure 9). A total of 75 sites have been sampled since the beginning of surveillance at this location.

Cleveland Harbor - An estimated 51.38 species are present as a result of 2017 data analysis; while 35 species were captured using all sampling gears (Figure 10). A total of 59 sites have been sampled since the beginning of surveillance at this location.

Sandusky Bay - An estimated 101.19 species are present as a result of 2013-2017 data analysis; while 41 species were captured using all sampling gears (Figure 11). A total of 193 sites have been sampled since the beginning of surveillance at this location.

Maumee Bay - An estimated 56.12 species are present as a result of 2013-2017 data analysis; while 48 species were captured using all sampling gears (Figure 12). A total of 189 sites have been sampled since the beginning of surveillance at this location.

Lake St. Clair - An estimated 40.47 species are present as a result of 2017 data analysis; while 25 species were captured using all sampling gears (Figure 13). A total of 30 sites have been sampled since the beginning of surveillance at this location.

6 Discussion

The 2017 field season was a continuation of annual sampling for the early detection of non-native species at Lake Erie locations using a vector based risk analysis since 2013 (USFWS 2016d; USFWS 2017). A total of 38,263 juvenile and adult fish (consisting of both native and non-native species) were collected by an assortment of gears during this survey.

Targeting juvenile and adult fish can be challenging due to fish behavior, refined habitat requirements, and gear avoidance. Non-native species at low abundances can be difficult to detect as juveniles or adults using traditional sampling gear. To account for this, multiple gear types were used to target juveniles and adults. Electrofishing and paired fyke nets generally have the highest species richness among gear types, however, paired fyke nets and bottom trawls seem to capture more individuals than the other gear types annually. The larger sample size for electrofishing and paired fyke nets (compared to other gears) may have played a role in these findings, especially in the eastern basin sampling locations. Despite high overall performance of electrofishing and paired fyke nets, it is recognized that a single sampling gear approach only provides a

partial representation of the juvenile and adult fish assemblage (Murphy and Willis 1996), and multi-gear approaches are required to adequately characterize fish communities (Jackson and Harvey 1997; Eggleton et al. 2010; Hoffman et al. 2011; Ruetz et al. 2007).

Ultimately, designing a long-term monitoring program is challenging due to the need to balance detection efficiency with available resources (Trebitz et al. 2009). These challenges become exacerbated when considering early detection monitoring for newly introduced non-native species because of the exorbitant amounts of effort and high survey efficiency (95% species detection) required. It is therefore beneficial to use results from previous sampling as a guide to adapt future survey design and improve overall sampling efficiency and effectiveness. For example, in Duluth-Superior Harbor, Lake Superior, Hoffman et al. (2011) used a re-sampling approach and found that using a targeted sampling design (i.e. resampled areas with high species richness) resulted in greater species richness and detected non-native species with a significantly higher probability than a spatially balanced random design (also see Trebitz et al. 2009). Although the effort required to detect rare (i.e. non-natives at first introduction) species remained large, non-metric multi-dimensional scaling analysis could also be used to determine whether gear types are capturing complementary or redundant species assemblage data (cf. Ruetz et al. 2007; Frances et al. 2014). For example, if two gear types capture redundant assemblages then the least efficient gear (according to the ability to catch unique species) could be eliminated or reduced, focusing additional effort towards the most efficient gear types, and thereby increase survey effort and theoretically sampling efficiency.

In closing, the early detection and monitoring program for non-native species will continue in Lake Erie during 2018. Survey design will continue to be critically re-evaluated following the next field season. All available options for increasing sampling efficiency to provide the most comprehensive early detection and monitoring program for non-native species will be considered.

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8 Figures and Tables

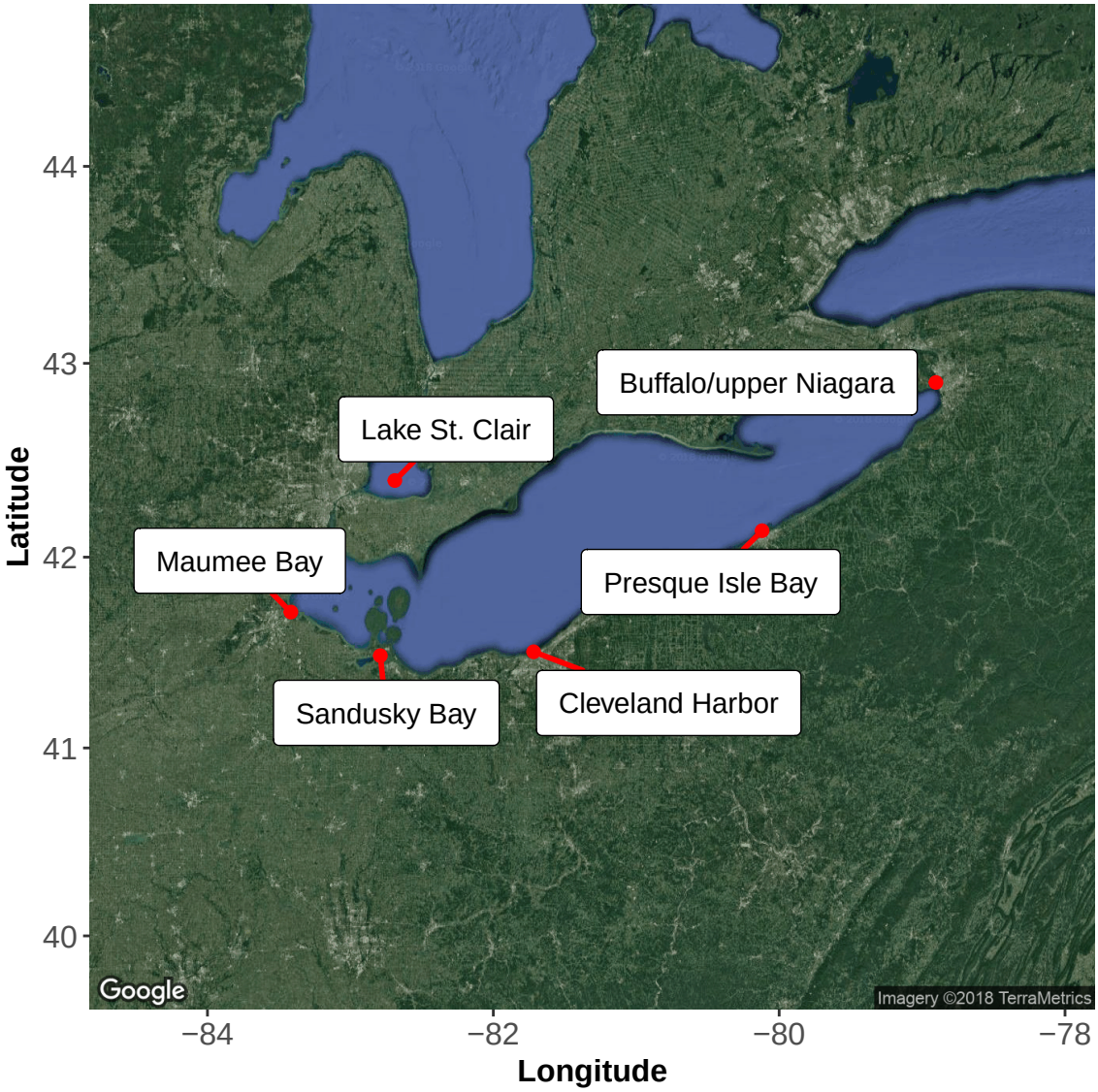

Figure 1: The Lake Erie Basin showing high risk areas and locations sampled.

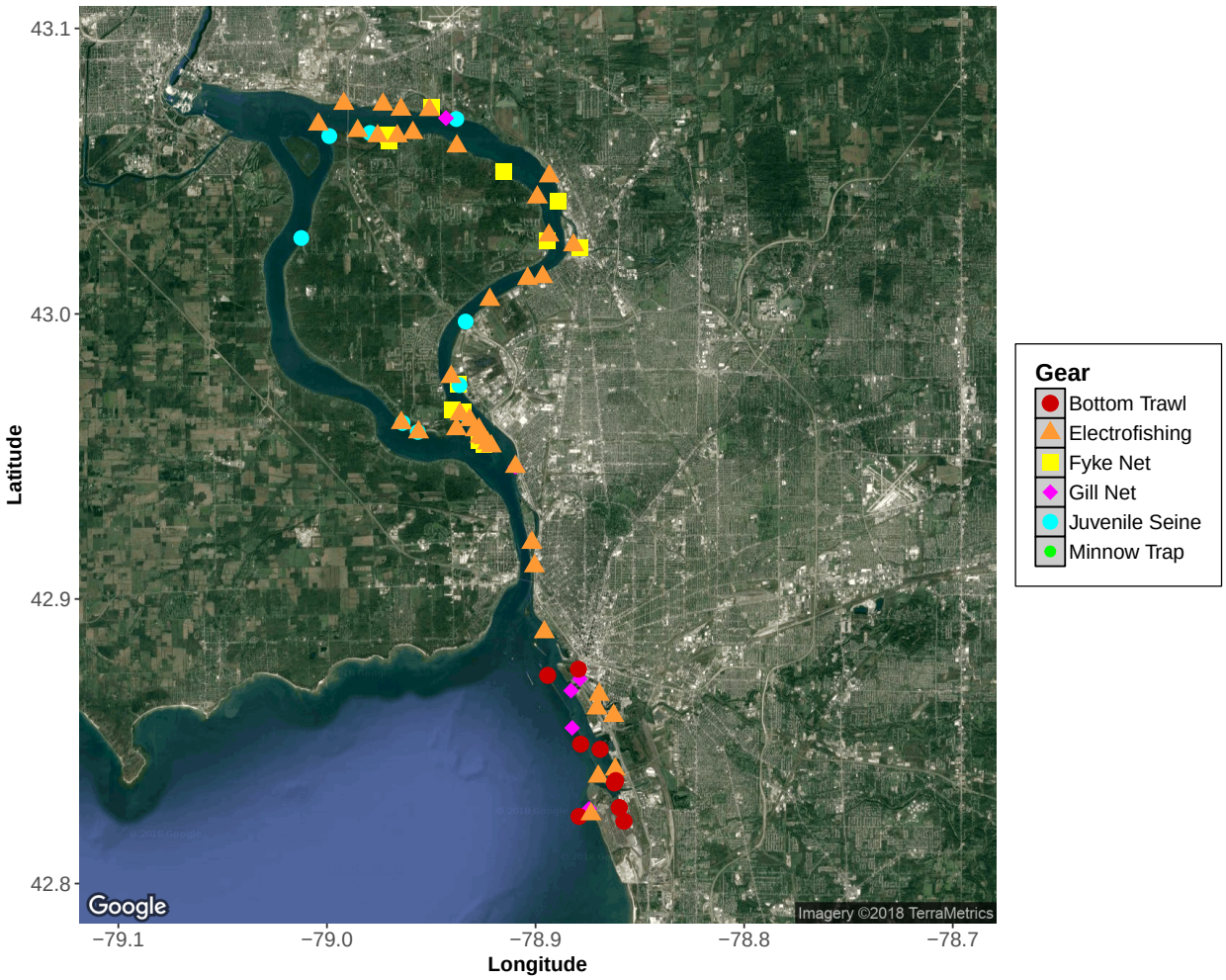

Figure 2: Buffalo/upper Niagara River showing locations sampled for juvenile and adult fish.

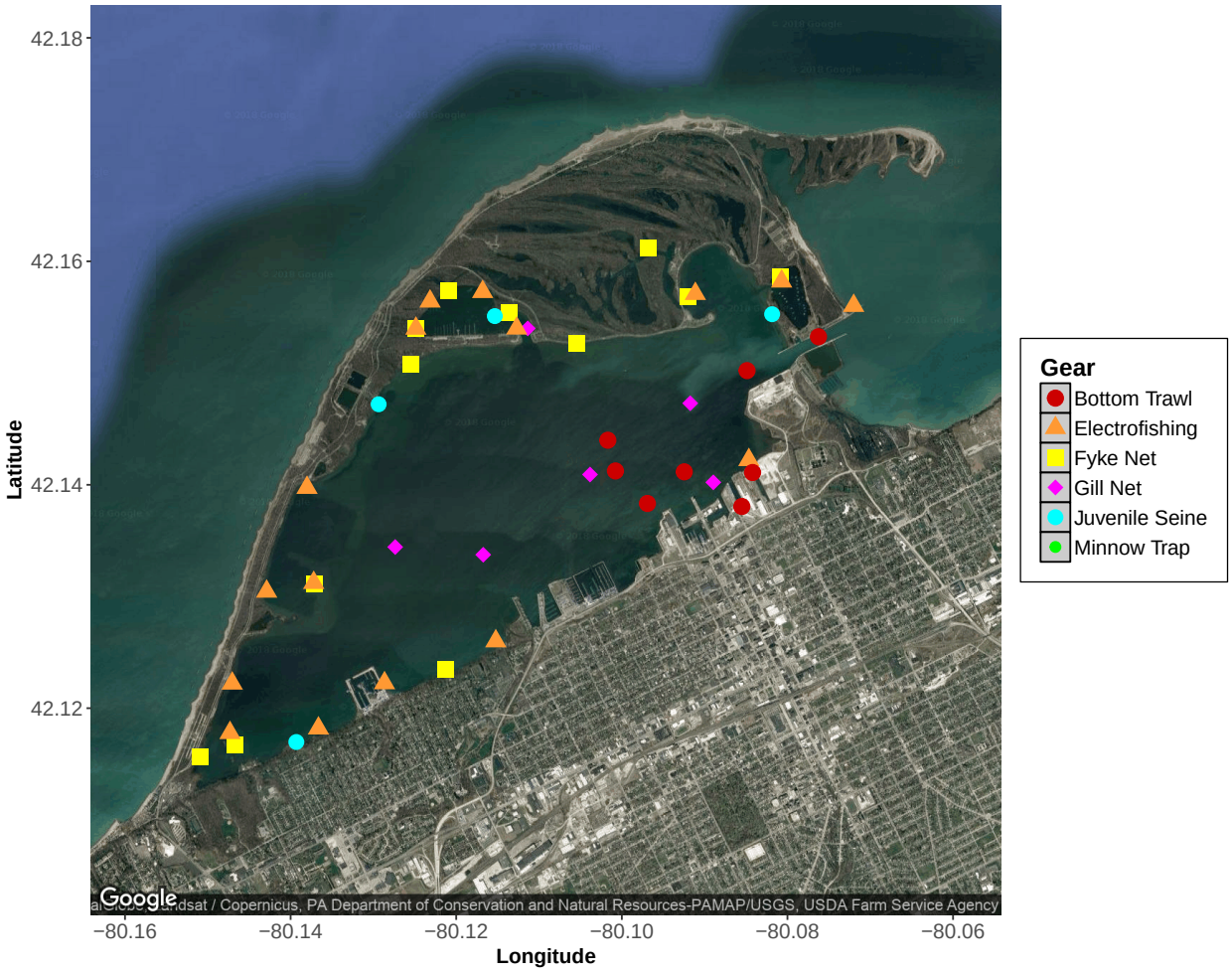

Figure 3: Presque Isle Bay showing locations sampled for juvenile and adult fish.

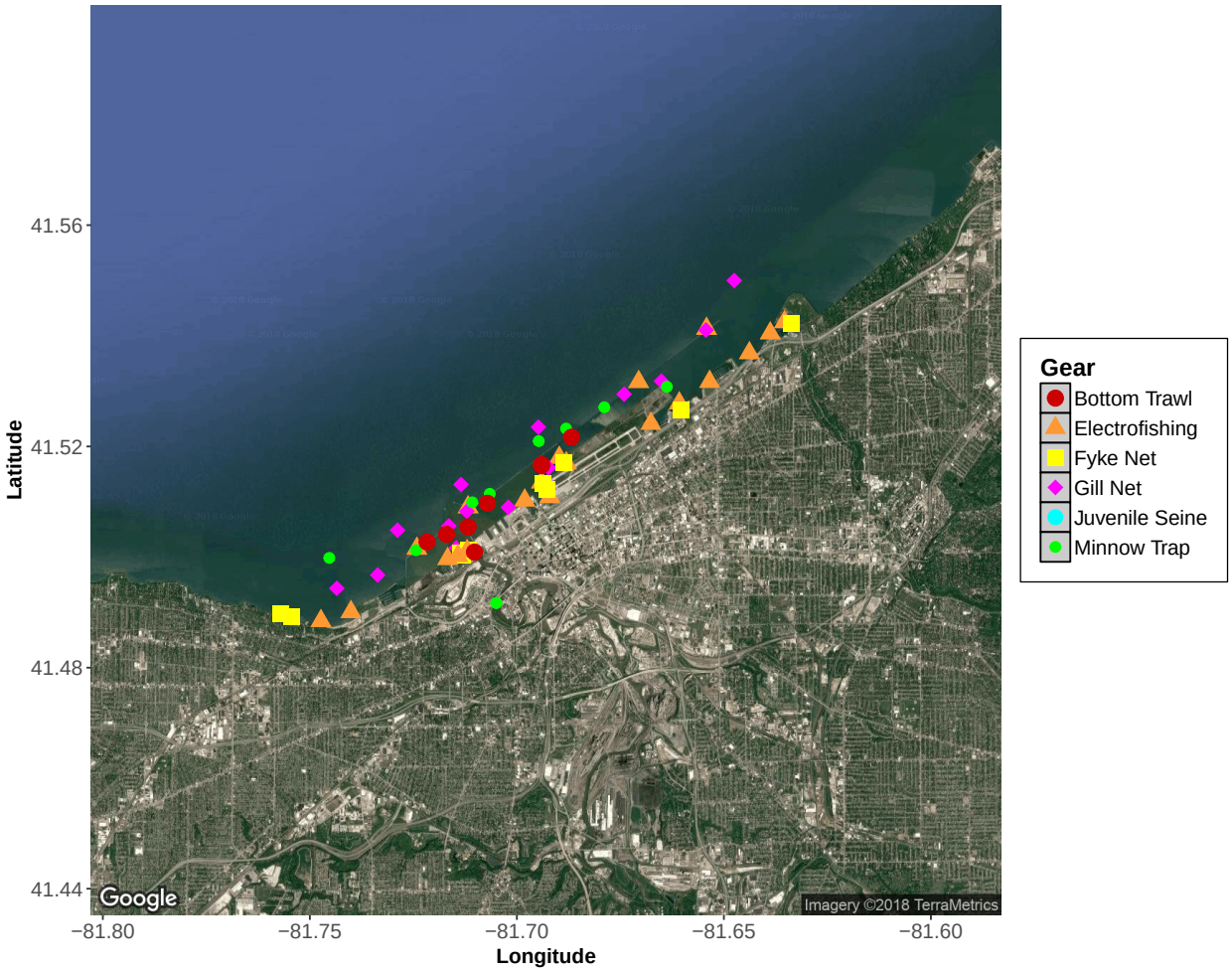

Figure 4: Cleveland Harbor showing locations sampled for juvenile and adult fish.

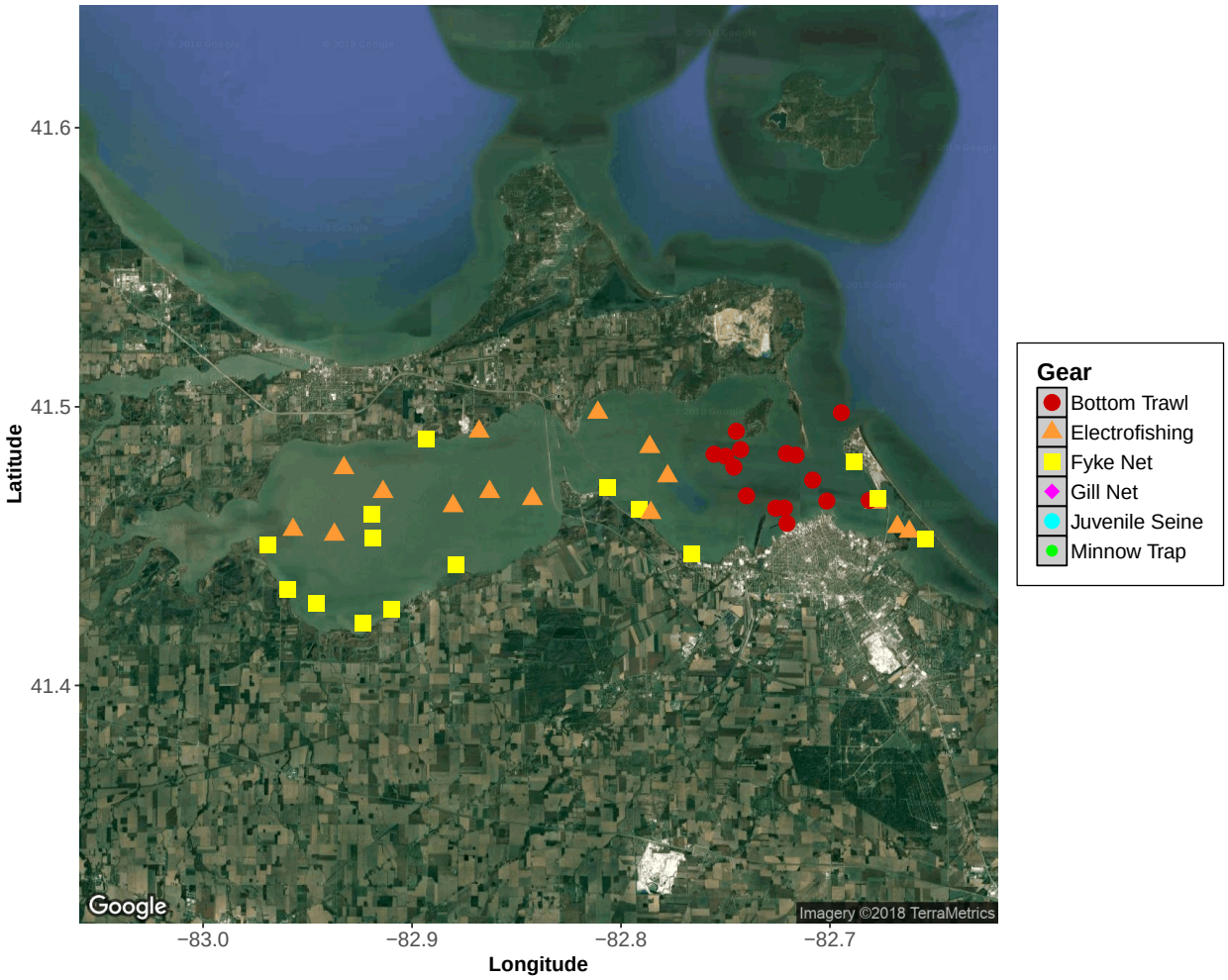

Figure 5: Sandusky Bay showing locations sampled for juvenile and adult fish.

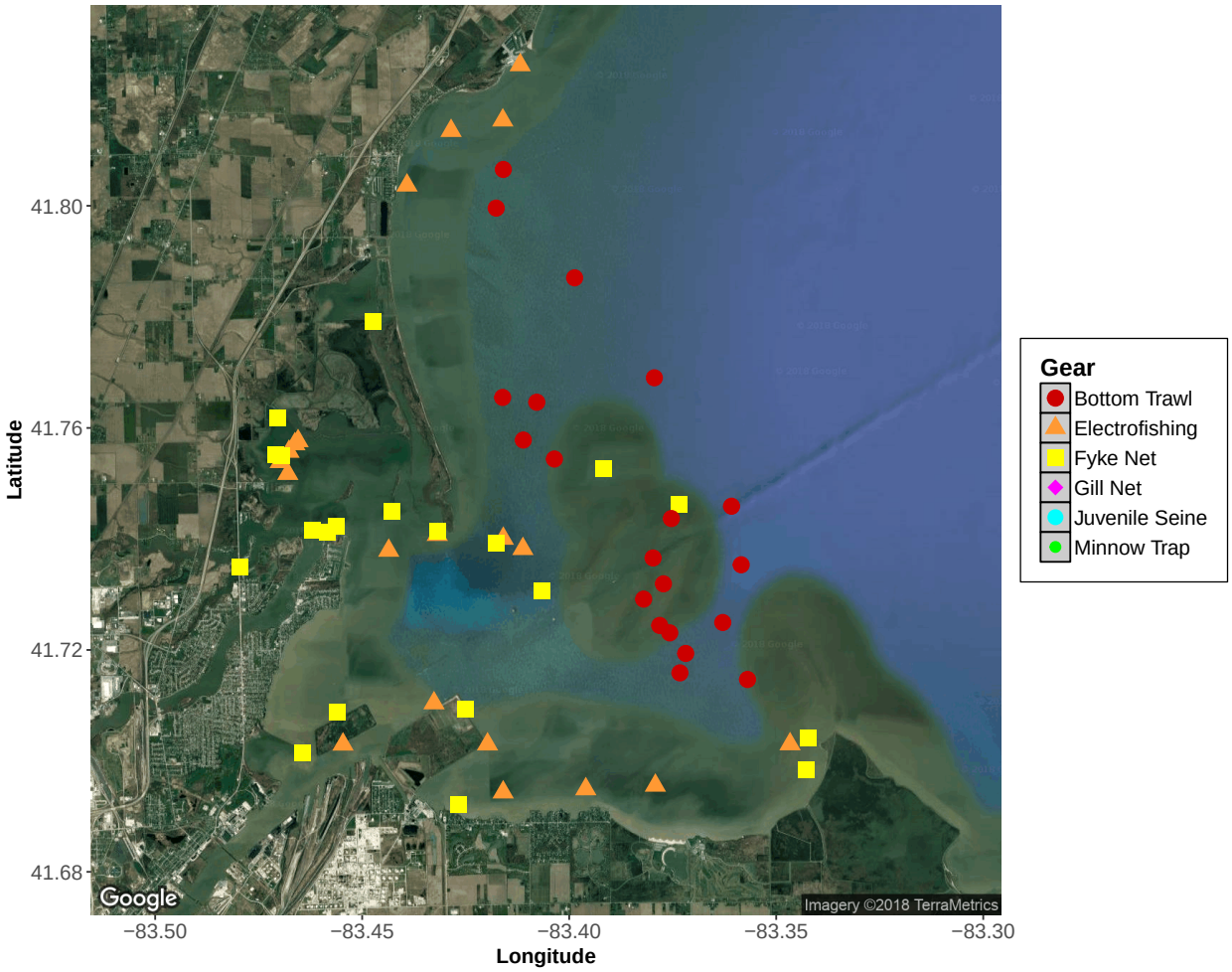

Figure 6: Maumee Bay showing locations sampled for juvenile and adult fish.

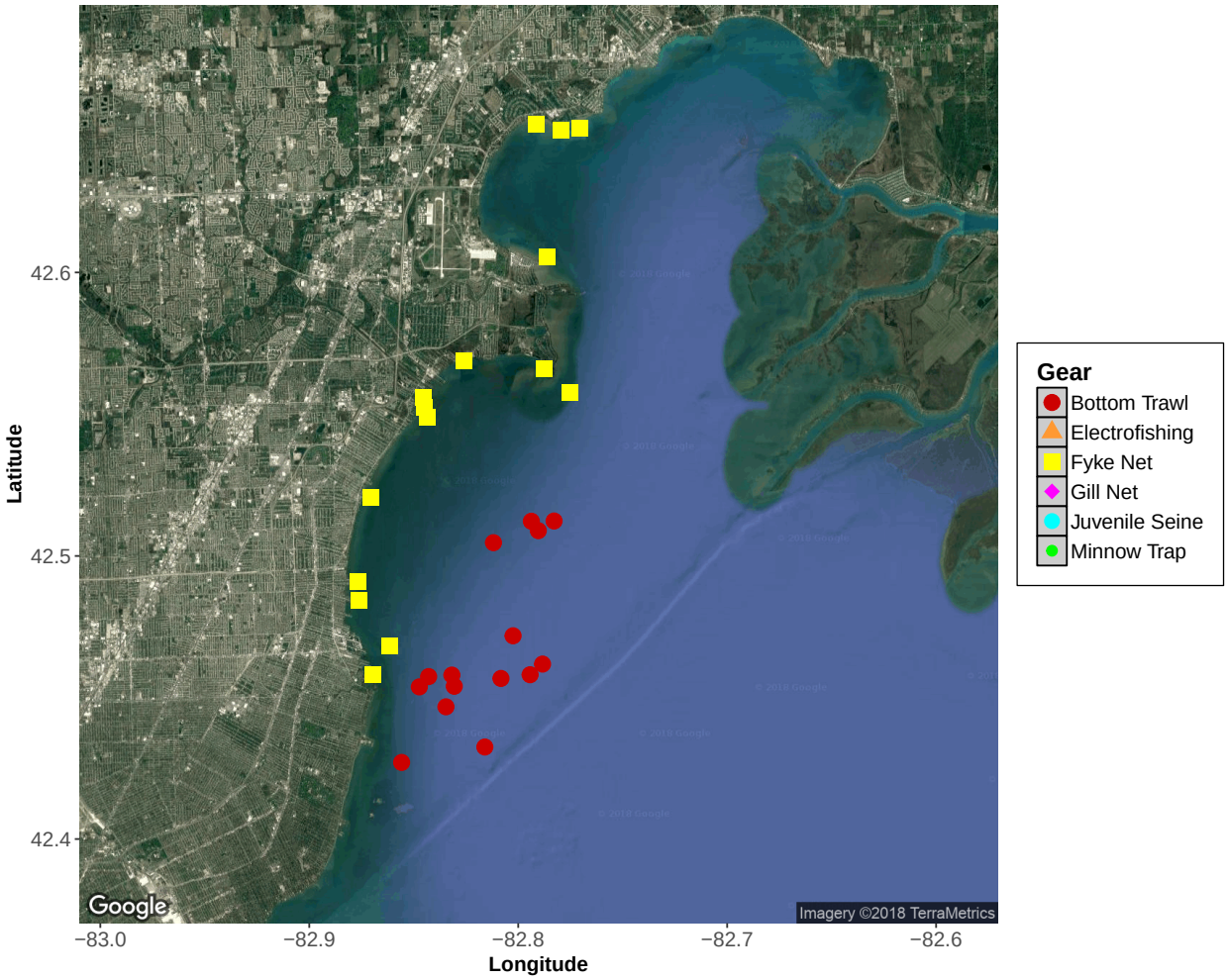

Figure 7: Lake St. Clair showing locations sampled for juvenile and adult fish.

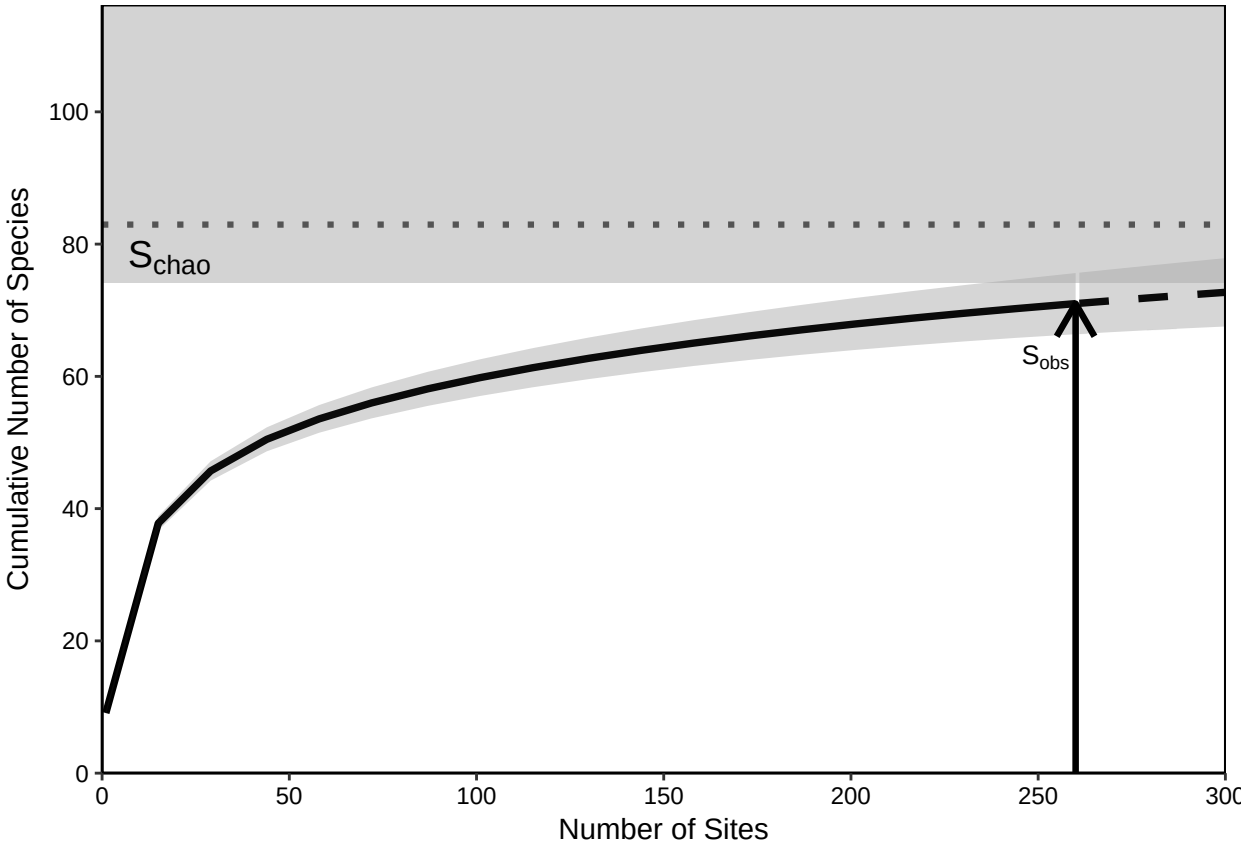

Figure 8: Species accumulation curves for all sampling gears fished for juvenile and adult fish combined in Buffalo/upper Niagara River, NY, 2013-2017. Schao = total number of species estimated based on the Chao asymptotic richness estimator (horizontal dotted line). Sobs = total number of species caught. Shaded regions represent the 95% confidence intervals.

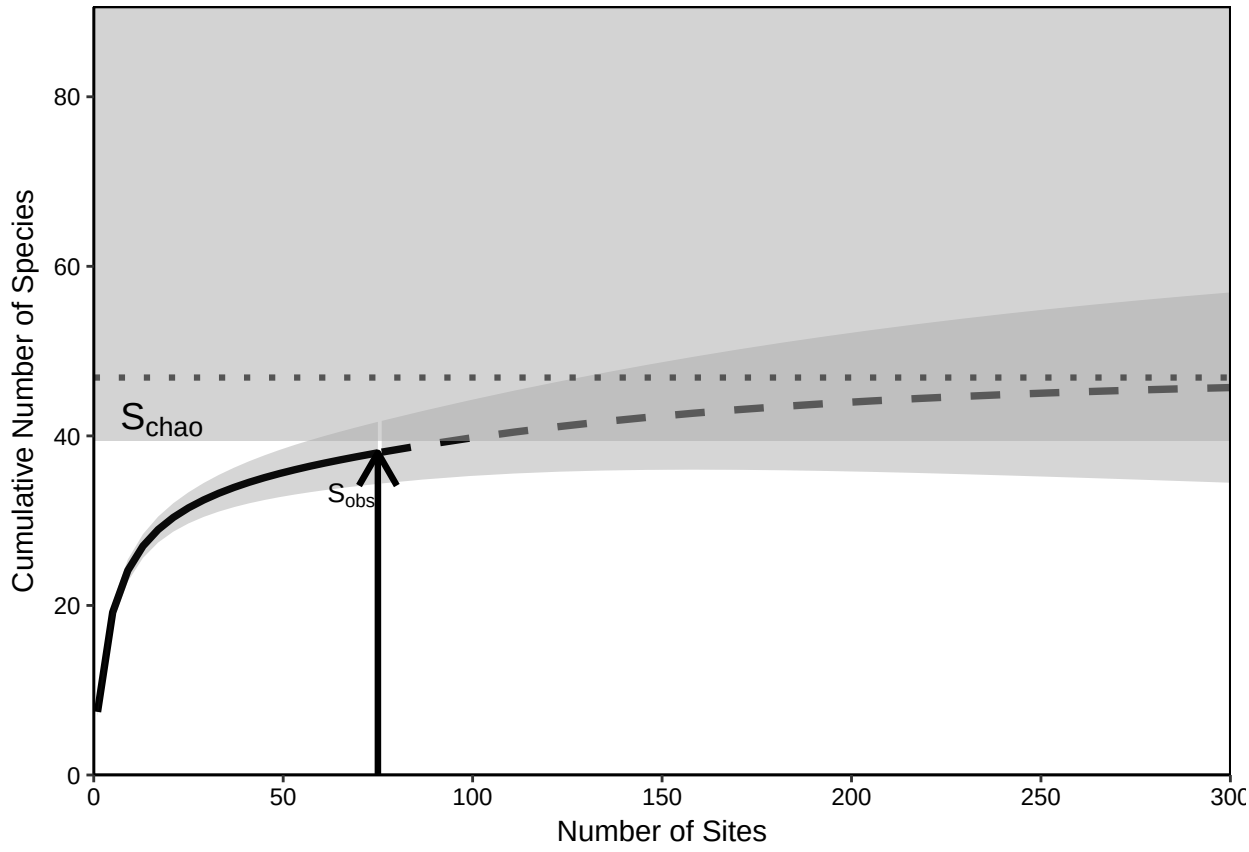

Figure 9: Species accumulation curves for all sampling gears fished for juvenile and adult fish combined in Presque Isle Bay, PA, 2016-2017. Schao = total number of species estimated based on the Chao asymptotic richness estimator (horizontal dotted line). Sobs = total number of species caught. Shaded regions represent the 95% confidence intervals.

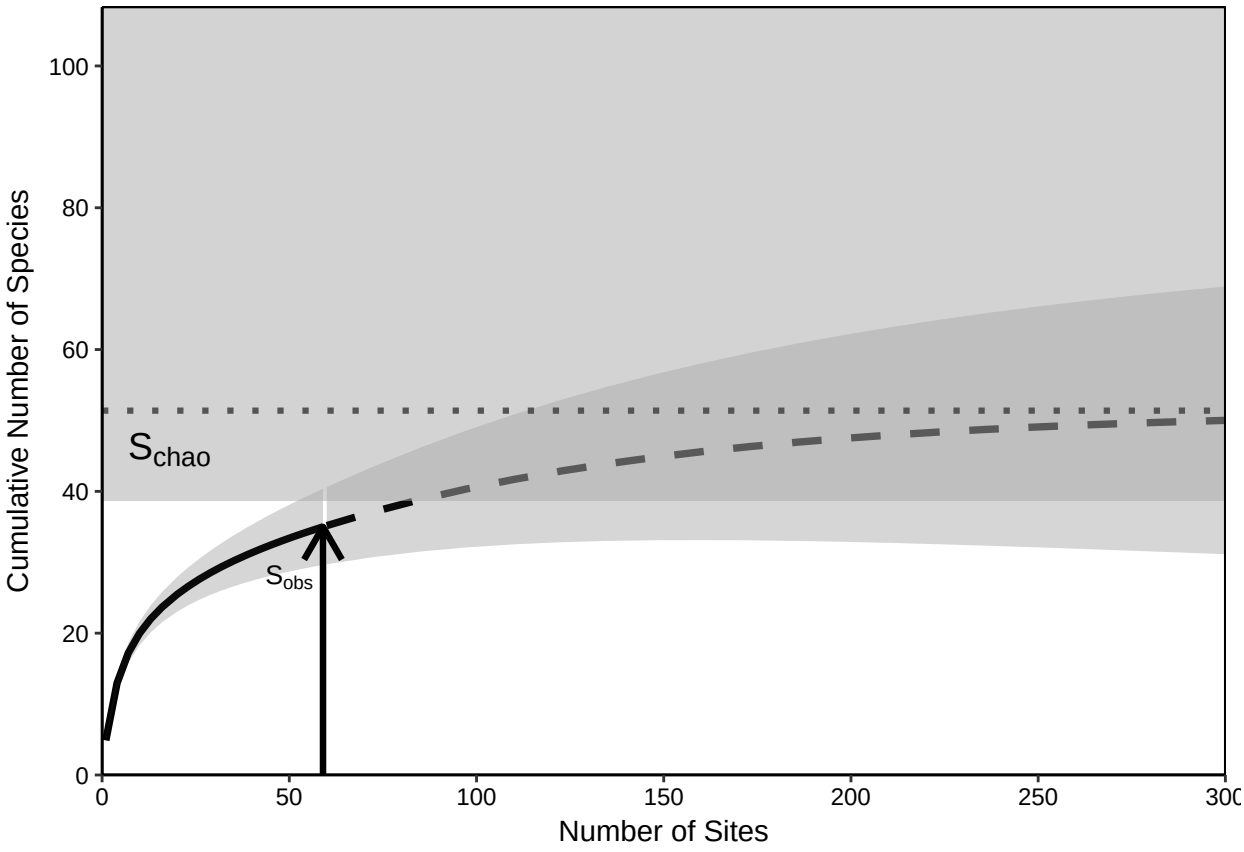

Figure 10: Species accumulation curves for all sampling gears fished for juvenile and adult fish combined in Cleveland Harbor, OH, 2017. Schao = total number of species estimated based on the Chao asymptotic richness estimator (horizontal dotted line). Sobs = total number of species caught. Shaded regions represent the 95% confidence intervals.

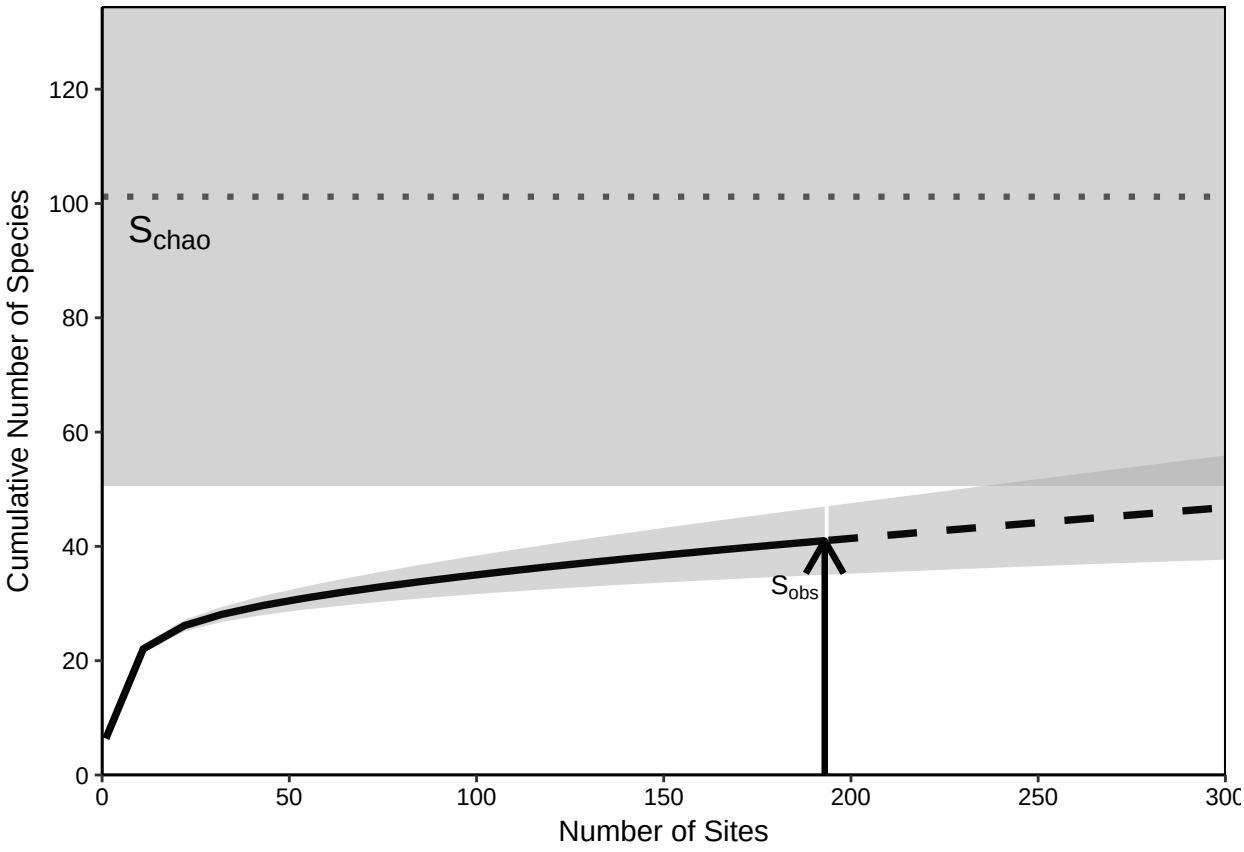

Figure 11: Species accumulation curves for all sampling gears fished for juvenile and adult fish combined in Sandusky Bay, OH, 2013-2017. Schao = total number of species estimated based on the Chao asymptotic richness estimator (horizontal dotted line). Sobs = total number of species caught. Shaded regions represent the 95% confidence intervals.

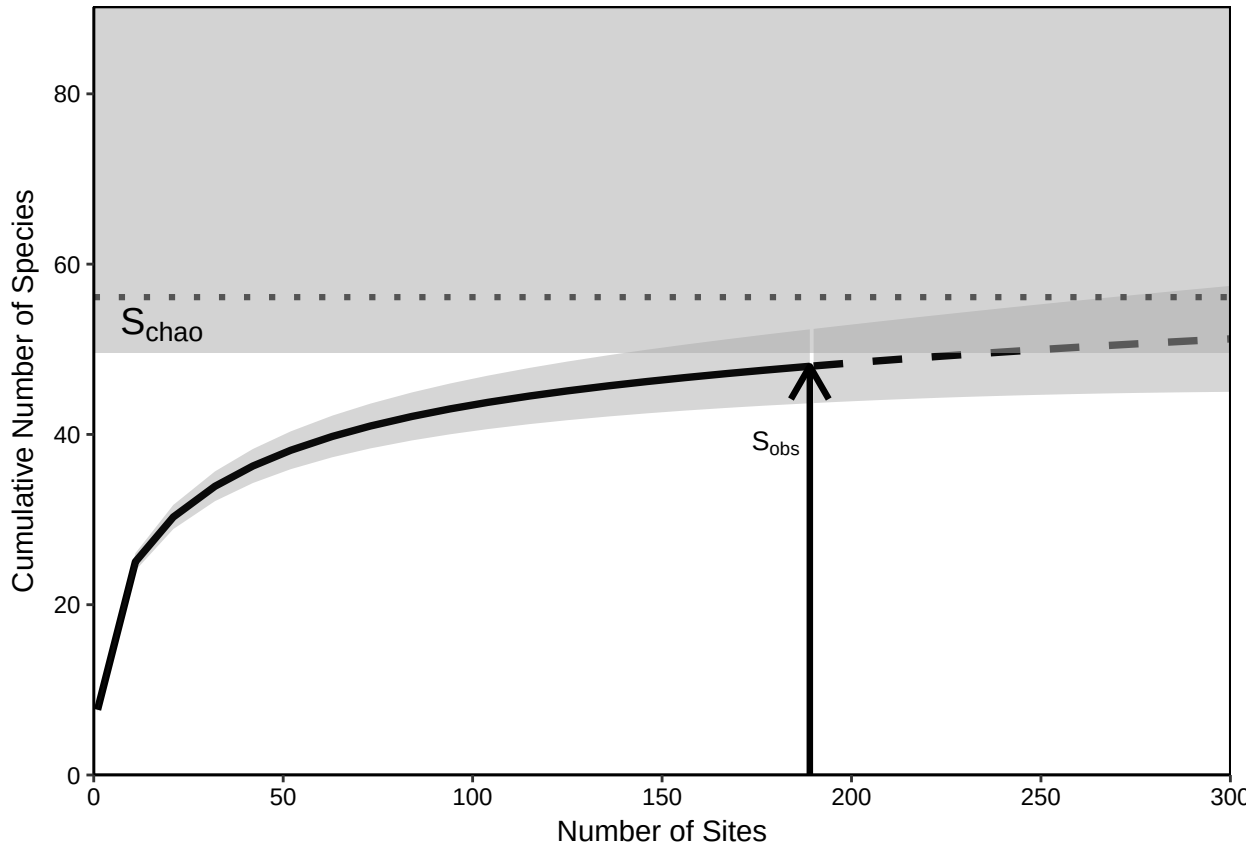

Figure 12: Species accumulation curves for all sampling gears fished for juvenile and adult fish combined in Maumee Bay, OH, 2013-2017. Schao = total number of species estimated based on the Chao asymptotic richness estimator (horizontal dotted line). Sobs = total number of species caught. Shaded regions represent the 95% confidence intervals.

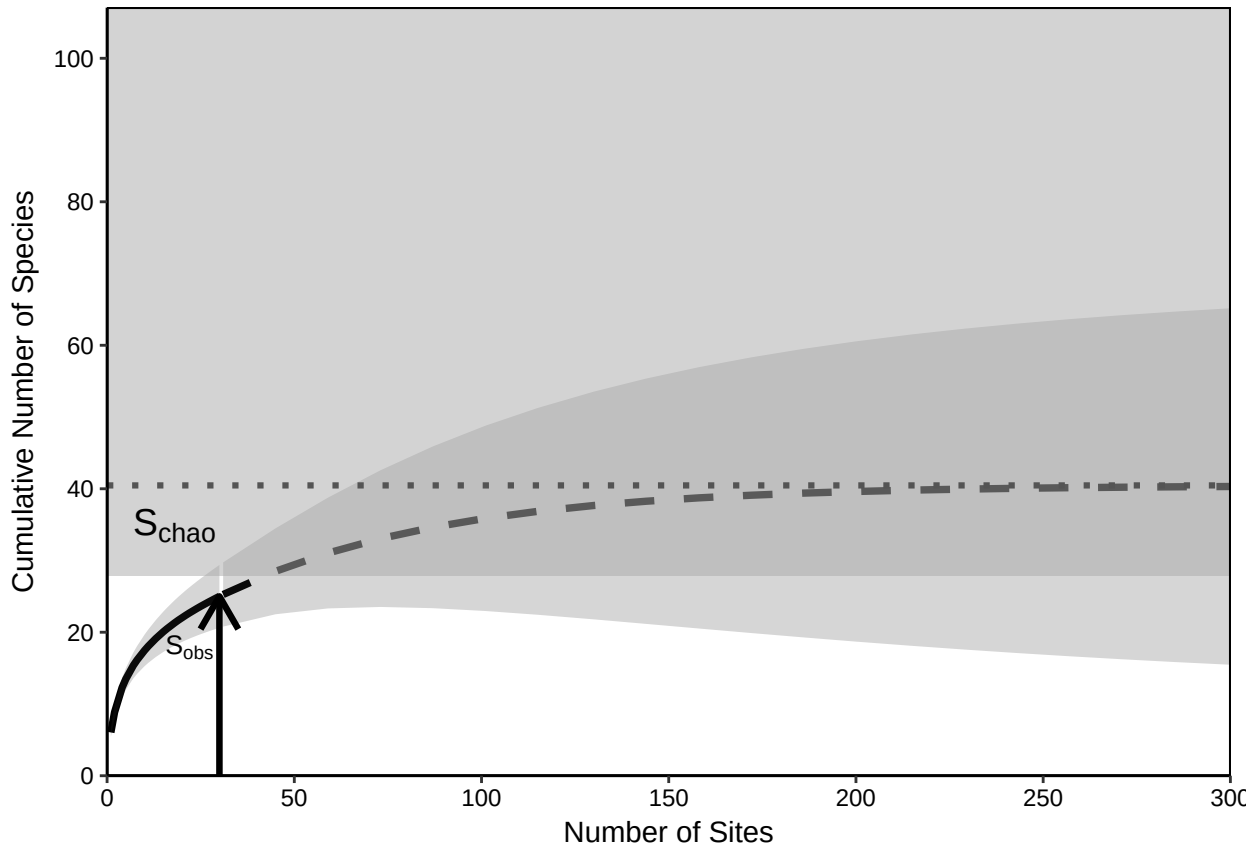

Figure 13: Species accumulation curves for all sampling gears fished for juvenile and adult fish combined in Lake St. Clair, MI, 2017. Schao = total number of species estimated based on the Chao asymptotic richness estimator (horizontal dotted line). Sobs = total number of species caught. Shaded regions represent the 95% confidence intervals.

Table 1: Catch summary for species captured during juvenile and adult fish sampling* in Buffalo/upper Niagara, NY, 2017.

			Electrofishing		Paired Fyke Net		Juvenile Seine		Gill Net		Bottom Trawl		
Scientific Name	Common Name	Status	Collected	CPUE (fish/hr)	Collected	CPUE (fish/set)	Collected	CPUE (fish/haul)	Collected	CPUE (fish/set)	Collected	CPUE (fish/minute)	Total
Alosa pseudoharengus	Alewife	Non-native	102	2.55	321	26.75	0	0.0	1	0.12	0	0.00	424
Fundulus diaphanus	Banded Killifish	Native	28	0.70	1	0.08	43	4.3	0	0.00	0	0.00	72
Ictiobus cyprinellus	Bigmouth Buffalo	Non-native	1	0.02	0	0.00	0	0.0	0	0.00	0	0.00	1
Pomoxis nigromaculatus	Black Crappie	Native	0	0.00	0	0.00	0	0.0	0	0.00	2	0.02	2
Moxostoma duquesnii	Black Redhorse	Native	1	0.02	0	0.00	0	0.0	0	0.00	0	0.00	1
Notropis heterodon	Blackchin Shiner	Native	0	0.00	0	0.00	1	0.1	0	0.00	0	0.00	1
Notropis heterolepis	Blacknose Shiner	Native	40	1.00	2	0.17	8	0.8	0	0.00	0	0.00	50
Lepomis macrochirus	Bluegill	Native	66	1.65	371	30.92	118	11.8	0	0.00	0	0.00	555
Pimephales notatus	Bluntnose Minnow	Native	387	9.68	1384	115.33	59	5.9	0	0.00	0	0.00	1830
Amia calva	Bowfin	Native	6	0.15	2	0.17	0	0.0	0	0.00	0	0.00	8
Labidesthes sicculus	Brook Silverside	Native	24	0.60	0	0.00	167	16.7	0	0.00	0	0.00	191
Ameiurus nebulosus	Brown Bullhead	Native	54	1.35	48	4.00	97	9.7	0	0.00	0	0.00	199
Umbra limi	Central Mudminnow	Native	0	0.00	0	0.00	4	0.4	0	0.00	0	0.00	4
Cyprinus carpio	Common Carp	Non-native	52	1.30	3	0.25	0	0.0	0	0.00	0	0.00	55
Notropis atherinoides	Emerald Shiner	Native	116	2.90	28	2.33	278	27.8	0	0.00	1	0.01	423
Aplodinotus grunniens	Freshwater Drum	Native	4	0.10	0	0.00	0	0.0	1	0.12	0	0.00	5
Dorosoma cepedianum	Gizzard Shad	Native	163	4.08	46	3.83	0	0.0	16	2.00	2	0.02	227
Moxostoma erythrurum	Golden Redhorse	Native	21	0.52	1	0.08	0	0.0	0	0.00	0	0.00	22
Notemigonus crysoleucas	Golden Shiner	Native	41	1.02	1	0.08	11	1.1	0	0.00	0	0.00	53
Carassius auratus	Goldfish	Non-native	44	1.10	0	0.00	0	0.0	0	0.00	0	0.00	44
Moxostoma valenciennesi	Greater Redhorse	Native	90	2.25	5	0.42	0	0.0	0	0.00	0	0.00	95

Table 1: Catch summary for species captured during juvenile and adult fish sampling* in Buffalo/upper Niagara, NY, 2017. *(continued)*

Scientific Name	Common Name	Status	Electrofishing		Paired Fyke Net		Juvenile Seine		Gill Net		Bottom Trawl		Total
			Collected	CPUE (fish/hr)	Collected	CPUE (fish/set)	Collected	CPUE (fish/haul)	Collected	CPUE (fish/set)	Collected	CPUE (fish/minute)	
Lepomis cyanellus	Green Sunfish	Native	0	0.00	6	0.50	0	0.0	0	0.00	0	0.00	6
Nocomis biguttatus	Hornyhead Chub	Native	6	0.15	0	0.00	0	0.0	0	0.00	0	0.00	6
Etheostoma nigrum	Johnny Darter	Native	0	0.00	9	0.75	7	0.7	0	0.00	0	0.00	16
Micropterus salmoides	Largemouth Bass	Native	225	5.62	326	27.17	32	3.2	0	0.00	1	0.01	584
Percina caprodes	Logperch	Native	6	0.15	3	0.25	1	0.1	3	0.38	0	0.00	13
Notropis volucellus	Mimic Shiner	Native	11	0.28	11	0.92	13	1.3	0	0.00	0	0.00	35
Hypertelium nigricans	Northern Hogsucker	Native	9	0.22	0	0.00	0	0.0	0	0.00	0	0.00	9
Esox lucius	Northern Pike	Native	1	0.02	1	0.08	0	0.0	0	0.00	1	0.01	3
Lepomis gibbosus	Pumpkinseed	Native	34	0.85	53	4.42	2	0.2	0	0.00	1	0.01	90
Osmerus mordax	Rainbow Smelt	Non-native	287	7.17	0	0.00	0	0.0	0	0.00	3	0.03	290
Oncorhynchus mykiss	Rainbow Trout	Non-native	1	0.02	0	0.00	0	0.0	0	0.00	0	0.00	1
Ambloplites rupestris	Rock Bass	Native	101	2.52	222	18.50	18	1.8	0	0.00	2	0.02	343
Neogobius melanostoma	Round Goby	Non-native	49	1.23	92	7.67	0	0.0	4	0.50	375	4.17	520
Scardinius erythrophthalmus	Rudd	Non-native	15	0.38	45	3.75	0	0.0	0	0.00	0	0.00	60
Cyprinella analostana	Satinfin Shiner	Non-native	10	0.25	0	0.00	0	0.0	0	0.00	0	0.00	10
Moxostoma macrolepidotum	Shorthead Redhorse	Native	3	0.08	13	1.08	0	0.0	0	0.00	2	0.02	18
Moxostoma arisurun	Silver Redhorse	Native	0	0.00	0	0.00	0	0.0	0	0.00	1	0.01	1
Micropterus dolomieui	Smallmouth Bass	Native	118	2.95	23	1.92	4	0.4	2	0.25	0	0.00	147
Cyprinella spiloptera	Spotfin Shiner	Native	10	0.25	7	0.58	17	1.7	0	0.00	1	0.01	35
Notropis hudsonius	Spottail Shiner	Native	251	6.28	189	15.75	56	5.6	18	2.25	12	0.13	526
Luxilus chrysocephalus	Striped Shiner	Native	21	0.52	2	0.17	1	0.1	0	0.00	0	0.00	24
Noturus gyrinus	Tadpole Madtom	Native	0	0.00	0	0.00	3	0.3	0	0.00	0	0.00	3
Percopsis omiscomaycus	Trout-Perch	Native	0	0.00	0	0.00	0	0.0	0	0.00	1	0.01	1

Table 1: Catch summary for species captured during juvenile and adult fish sampling* in Buffalo/upper Niagara, NY, 2017. *(continued)*

Scientific Name	Common Name	Status	Electrofishing		Paired Fyke Net		Juvenile Seine		Gill Net		Bottom Trawl		Total
			Collected	CPUE (fish/hr)	Collected	CPUE (fish/set)	Collected	CPUE (fish/haul)	Collected	CPUE (fish/set)	Collected	CPUE (fish/minute)	
Sander vitreum	Walleye	Native	7	0.18	0	0.00	0	0.0	0	0.00	2	0.02	9
Morone chrysops	White Bass	Native	0	0.00	0	0.00	0	0.0	0	0.00	2	0.02	2
Pomoxis annularis	White Crappie	Native	0	0.00	3	0.25	35	3.5	0	0.00	0	0.00	38
Morone americana	White Perch	Non-native	32	0.80	27	2.25	0	0.0	0	0.00	8	0.09	67
Catostomus commersonii	White Sucker	Native	339	8.47	12	1.00	3	0.3	0	0.00	9	0.10	363
Ameiurus natalis	Yellow Bullhead	Native	3	0.08	0	0.00	0	0.0	0	0.00	0	0.00	3
Perca flavescens	Yellow Perch	Native	448	11.20	63	5.25	0	0.0	11	1.38	114	1.27	636

* Sampling effort for electrofishing was 6.7 hours, paired fyke nets was 12 overnight sets, juvenile seine was 10 hauls, gill netting was 8 sets, and bottom trawling was 9 ten minute tows.

Table 2: Catch summary for species captured during juvenile and adult fish sampling* in Presque Isle Bay, PA, 2017.

			Electrofishing		Paired Fyke Net		Juvenile Seine		Gill Net		Bottom Trawl		
Scientific Name	Common Name	Status	Collected	CPUE (fish/hr)	Collected	CPUE (fish/set)	Collected	CPUE (fish/haul)	Collected	CPUE (fish/set)	Collected	CPUE (fish/minute)	Total
Alosa pseudoharengus	Alewife	Non-native	0	0.00	0	0.00	0	0.00	85	14.17	0	0.00	85
Fundulus diaphanus	Banded Killifish	Native	41	2.56	6	0.50	99	24.75	0	0.00	0	0.00	146
Pomoxis nigromaculatus	Black Crappie	Native	16	1.00	78	6.50	0	0.00	0	0.00	0	0.00	94
Notropis heterolepis	Blacknose Shiner	Native	1	0.06	0	0.00	0	0.00	0	0.00	0	0.00	1
Lepomis macrochirus	Bluegill	Native	136	8.50	1217	101.42	2	0.50	0	0.00	14	0.18	1369
Pimephales notatus	Bluntnose Minnow	Native	34	2.12	10	0.83	5	1.25	0	0.00	0	0.00	49
Amia calva	Bowfin	Native	17	1.06	3	0.25	0	0.00	0	0.00	0	0.00	20
Labidesthes sicculus	Brook Silverside	Native	41	2.56	0	0.00	673	168.25	0	0.00	0	0.00	714
Ameiurus nebulosus	Brown Bullhead	Native	24	1.50	16	1.33	0	0.00	0	0.00	3	0.04	43
Umbra limi	Central Mudminnow	Native	2	0.12	0	0.00	0	0.00	0	0.00	0	0.00	2
Cyprinus carpio	Common Carp	Non-native	9	0.56	0	0.00	0	0.00	0	0.00	0	0.00	9
Notropis atherinoides	Emerald Shiner	Native	41	2.56	0	0.00	50	12.50	2	0.33	5	0.06	98
Dorosoma cepedianum	Gizzard Shad	Native	165	10.31	10	0.83	0	0.00	27	4.50	8	0.10	210
Notemigonus crysoleucas	Golden Shiner	Native	21	1.31	4	0.33	0	0.00	0	0.00	0	0.00	25
Carassius auratus	Goldfish	Non-native	16	1.00	0	0.00	0	0.00	0	0.00	0	0.00	16
Micropterus salmoides	Largemouth Bass	Native	128	8.00	16	1.33	0	0.00	0	0.00	0	0.00	144
Percina caprodes	Logperch	Native	0	0.00	0	0.00	0	0.00	2	0.33	0	0.00	2
Lepisosteus osseus	Longnose Gar	Native	1	0.06	0	0.00	0	0.00	0	0.00	0	0.00	1
Notropis volucellus	Mimic Shiner	Native	106	6.62	15	1.25	206	51.50	2	0.33	14	0.18	343
Esox lucius	Northern Pike	Native	4	0.25	0	0.00	0	0.00	0	0.00	0	0.00	4
Lepomis gibbosus	Pumpkinseed	Native	72	4.50	145	12.08	1	0.25	0	0.00	2	0.02	220
Osmerus mordax	Rainbow Smelt	Non-native	0	0.00	0	0.00	0	0.00	0	0.00	2	0.02	2
Oncorhynchus mykiss	Rainbow Trout	Non-native	6	0.38	0	0.00	0	0.00	0	0.00	0	0.00	6

Table 2: Catch summary for species captured during juvenile and adult fish sampling* in Presque Isle Bay, PA, 2017. *(continued)*

Scientific Name	Common Name	Status	Electrofishing		Paired Fyke Net		Juvenile Seine		Gill Net		Bottom Trawl		Total
			Collected	CPUE (fish/hr)	Collected	CPUE (fish/set)	Collected	CPUE (fish/haul)	Collected	CPUE (fish/set)	Collected	CPUE (fish/minute)	
Ambloplites rupestris	Rock Bass	Native	13	0.81	49	4.08	0	0.00	0	0.00	8	0.10	70
Neogobius melanostoma	Round Goby	Non-native	2	0.12	152	12.67	0	0.00	5	0.83	65	0.81	224
Micropterus dolomieui	Smallmouth Bass	Native	0	0.00	2	0.17	0	0.00	0	0.00	0	0.00	2
Notropis hudsonius	Spottail Shiner	Native	0	0.00	2	0.17	0	0.00	18	3.00	1	0.01	21
Lepisosteus oculatus	Spotted Gar	Native	1	0.06	0	0.00	0	0.00	0	0.00	0	0.00	1
Percopsis omiscomaycus	Trout-Perch	Native	0	0.00	0	0.00	0	0.00	0	0.00	17	0.21	17
Lepomis gulosus	Warmouth	Native	3	0.19	8	0.67	0	0.00	0	0.00	0	0.00	11
Morone chrysops	White Bass	Native	0	0.00	0	0.00	0	0.00	0	0.00	1	0.01	1
Pomoxis annularis	White Crappie	Native	0	0.00	0	0.00	0	0.00	0	0.00	6	0.08	6
Morone americana	White Perch	Non-native	1	0.06	1	0.08	0	0.00	107	17.83	19	0.24	128
Catostomus commersonii	White Sucker	Native	1	0.06	0	0.00	0	0.00	0	0.00	0	0.00	1
Ameiurus natalis	Yellow Bullhead	Native	1	0.06	20	1.67	0	0.00	0	0.00	0	0.00	21
Perca flavescens	Yellow Perch	Native	617	38.56	127	10.58	1	0.25	125	20.83	627	7.84	1497

* Sampling effort for electrofishing was 2.7 hours, paired fyke nets was 12 overnight sets, juvenile seine was 4 hauls, gill netting was 6 sets, and bottom trawling was 8 ten minute tows.

Table 3: Catch summary for species captured during juvenile and adult fish sampling* in Cleveland Harbor, OH, 2017.

Scientific Name	Common Name	Status	Electrofishing		Paired Fyke Net		Gill Net		Minnow Trap		Bottom Trawl		Total
			Collected	CPUE (fish/hr)	Collected	CPUE (fish/set)	Collected	CPUE (fish/set)	Collected	CPUE (fish/haul)	Collected	CPUE (fish/minute)	
Alosa pseudoharengus	Alewife	Non-native	1	0.06	0	0.00	1	0.17	0	0.00	5	0.05	7
Pomoxis nigromaculatus	Black Crappie	Native	0	0.00	2	0.17	0	0.00	0	0.00	0	0.00	2
Lepomis macrochirus	Bluegill	Native	45	2.81	1057	88.08	0	0.00	5	1.25	0	0.00	1107
Pimephales notatus	Bluntnose Minnow	Native	1	0.06	0	0.00	0	0.00	0	0.00	0	0.00	1
Amia calva	Bowfin	Native	1	0.06	0	0.00	0	0.00	0	0.00	0	0.00	1
Labidesthes sicculus	Brook Silverside	Native	4	0.25	0	0.00	0	0.00	0	0.00	0	0.00	4
Ameiurus nebulosus	Brown Bullhead	Native	1	0.06	6	0.50	0	0.00	0	0.00	0	0.00	7
Ictalurus punctatus	Channel Catfish	Native	0	0.00	0	0.00	0	0.00	1	0.25	5	0.05	6
Cyprinus carpio	Common Carp	Non-native	16	1.00	0	0.00	0	0.00	0	0.00	1	0.01	17
Notropis atherinoides	Emerald Shiner	Native	86	5.38	1	0.08	11	1.83	0	0.00	29	0.29	127
Aplodinotus grunniens	Freshwater Drum	Native	19	1.19	0	0.00	0	0.00	0	0.00	1	0.01	20
Dorosoma cepedianum	Gizzard Shad	Native	16	1.00	0	0.00	12	2.00	0	0.00	34	0.34	62
Moxostoma erythrurum	Golden Redhorse	Native	2	0.12	0	0.00	0	0.00	0	0.00	0	0.00	2
Notemigonus crysoleucas	Golden Shiner	Native	32	2.00	0	0.00	0	0.00	0	0.00	0	0.00	32
Carassius auratus	Goldfish	Non-native	1	0.06	0	0.00	0	0.00	0	0.00	0	0.00	1
Lepomis cyanellus	Green Sunfish	Native	0	0.00	1	0.08	0	0.00	0	0.00	0	0.00	1
Couesius plumbeus	Lake Chub	Non-native	1	0.06	0	0.00	0	0.00	0	0.00	0	0.00	1
Micropterus salmoides	Largemouth Bass	Native	78	4.88	1	0.08	0	0.00	0	0.00	0	0.00	79

Table 3: Catch summary for species captured during juvenile and adult fish sampling* in Cleveland Harbor, OH, 2017. *(continued)*

Scientific Name	Common Name	Status	Electrofishing		Paired Fyke Net		Gill Net		Minnow Trap		Bottom Trawl		Total
			Collected	CPUE (fish/hr)	Collected	CPUE (fish/set)	Collected	CPUE (fish/set)	Collected	CPUE (fish/haul)	Collected	CPUE (fish/minute)	
Percina caprodes	Logperch	Native	5	0.31	0	0.00	1	0.17	0	0.00	0	0.00	6
Notropis volucellus	Mimic Shiner	Native	69	4.31	8	0.67	0	0.00	0	0.00	102	1.02	179
Lepomis gibbosus	Pumpkinseed	Native	4	0.25	8	0.67	0	0.00	0	0.00	0	0.00	12
Osmerus mordax	Rainbow Smelt	Non-native	0	0.00	0	0.00	0	0.00	0	0.00	1	0.01	1
Ambloplites rupestris	Rock Bass	Native	80	5.00	115	9.58	0	0.00	0	0.00	0	0.00	195
Neogobius melanostoma	Round Goby	Non-native	17	1.06	50	4.17	0	0.00	15	3.75	46	0.46	128
Micropterus dolomieui	Smallmouth Bass	Native	80	5.00	0	0.00	0	0.00	0	0.00	0	0.00	80
Notropis hudsonius	Spottail Shiner	Native	4	0.25	0	0.00	4	0.67	11	2.75	2	0.02	21
Minytrema melanops	Spotted Sucker	Native	5	0.31	0	0.00	0	0.00	0	0.00	0	0.00	5
Percopsis omiscomaycus	Trout-Perch	Native	0	0.00	0	0.00	0	0.00	0	0.00	1	0.01	1
Sander vitreum	Walleye	Native	4	0.25	0	0.00	1	0.17	0	0.00	0	0.00	5
Morone chrysops	White Bass	Native	0	0.00	1	0.08	2	0.33	0	0.00	0	0.00	3
Morone americana	White Perch	Non-native	0	0.00	3	0.25	363	60.50	3	0.75	23	0.23	392
Catostomus commersonii	White Sucker	Native	0	0.00	1	0.08	0	0.00	0	0.00	0	0.00	1
Ameiurus natalis	Yellow Bullhead	Native	5	0.31	34	2.83	0	0.00	0	0.00	0	0.00	39
Perca flavescens	Yellow Perch	Native	158	9.88	89	7.42	106	17.67	0	0.00	29	0.29	382

* Sampling effort for electrofishing was 3.3 hours, paired fyke nets was 10 overnight sets, gill netting was 15 sets, minnow trap was 10 hauls, and bottom trawling was 10 ten minute tows.

Table 4: Catch summary for species captured during juvenile and adult fish sampling* in Sandusky Bay, OH, 2017.

			Electrofishing		Paired Fyke Net		Bottom Trawl		
Scientific Name	Common Name	Status	Collected	CPUE (fish/hr)	Collected	CPUE (fish/set)	Collected	CPUE (fish/minute)	Total
Ictalurus melas	Black Bullhead	Native	0	0.00	3	0.20	0	0.00	3
Pomoxis nigromaculatus	Black Crappie	Native	0	0.00	11	0.73	0	0.00	11
Lepomis macrochirus	Bluegill	Native	0	0.00	8	0.53	16	0.21	24
Labidesthes sicculus	Brook Silverside	Native	26	1.73	0	0.00	0	0.00	26
Ameiurus nebulosus	Brown Bullhead	Native	0	0.00	17	1.13	0	0.00	17
Ictalurus punctatus	Channel Catfish	Native	0	0.00	32	2.13	3	0.04	35
Cyprinus carpio	Common Carp	Non-native	0	0.00	4	0.27	1	0.01	5
Notropis atherinoides	Emerald Shiner	Native	4	0.27	0	0.00	0	0.00	4
Aplodinotus grunniens	Freshwater Drum	Native	2	0.13	106	7.07	43	0.57	151
Dorosoma cepedianum	Gizzard Shad	Native	170	11.33	123	8.20	477	6.36	770
Carassius auratus	Goldfish	Non-native	1	0.07	2	0.13	0	0.00	3
Notropis volucellus	Mimic Shiner	Native	0	0.00	26	1.73	104	1.39	130
Lepomis gibbosus	Pumpkinseed	Native	1	0.07	1	0.07	0	0.00	2
Osmerus mordax	Rainbow Smelt	Non-native	0	0.00	0	0.00	1820	24.27	1820
Neogobius melanostoma	Round Goby	Non-native	0	0.00	92	6.13	7	0.09	99
Notropis stramineus	Sand Shiner	Native	0	0.00	51	3.40	0	0.00	51
Ictiobus bubalus	Smallmouth Buffalo	Non-native	0	0.00	3	0.20	1	0.01	4
Notropis hudsonius	Spottail Shiner	Native	0	0.00	14	0.93	0	0.00	14
Sander vitreum	Walleye	Native	3	0.20	0	0.00	3	0.04	6
Morone chrysops	White Bass	Native	0	0.00	40	2.67	0	0.00	40
Pomoxis annularis	White Crappie	Native	0	0.00	9	0.60	0	0.00	9
Morone americana	White Perch	Non-native	2	0.13	1066	71.07	606	8.08	1674
Ameiurus natalis	Yellow Bullhead	Native	0	0.00	1	0.07	0	0.00	1
Perca flavescens	Yellow Perch	Native	0	0.00	58	3.87	14	0.19	72

* Sampling effort for electrofishing was 2.5 hours, paired fyke nets was 15 overnight sets, and bottom trawling was 15 five minute tows.

Table 5: Catch summary for species captured during juvenile and adult fish sampling* in Maumee Bay, OH, 2017.

			Electrofishing		Paired Fyke Net		Bottom Trawl		
Scientific Name	Common Name	Status	Collected	CPUE (fish/hr)	Collected	CPUE (fish/set)	Collected	CPUE (fish/minute)	Total
Pomoxis nigromaculatus	Black Crappie	Native	0	0.00	1	0.05	0	0.00	1
Moxostoma duquesnii	Black Redhorse	Native	1	0.05	0	0.00	0	0.00	1
Lepomis macrochirus	Bluegill	Native	16	0.80	2385	119.25	0	0.00	2401
Pimephales notatus	Bluntnose Minnow	Native	1	0.05	12	0.60	0	0.00	13
Amia calva	Bowfin	Native	4	0.20	0	0.00	0	0.00	4
Labidesthes sicculus	Brook Silverside	Native	46	2.30	0	0.00	0	0.00	46
Ameiurus nebulosus	Brown Bullhead	Native	31	1.55	59	2.95	0	0.00	90
Ictalurus punctatus	Channel Catfish	Native	0	0.00	26	1.30	504	5.04	530
Cyprinus carpio	Common Carp	Non-native	0	0.00	2	0.10	0	0.00	2
Notropis atherinoides	Emerald Shiner	Native	41	2.05	43	2.15	8	0.08	92
Aplodinotus grunniens	Freshwater Drum	Native	3	0.15	10	0.50	37	0.37	50
Dorosoma cepedianum	Gizzard Shad	Native	381	19.05	72	3.60	402	4.02	855
Notemigonus crysoleucas	Golden Shiner	Native	5	0.25	2	0.10	0	0.00	7
Carassius auratus	Goldfish	Non-native	5	0.25	1	0.05	0	0.00	6
Etheostoma nigrum	Johnny Darter	Native	0	0.00	1	0.05	6	0.06	7
Micropterus salmoides	Largemouth Bass	Native	3	0.15	12	0.60	0	0.00	15
Percina caprodes	Logperch	Native	1	0.05	45	2.25	9	0.09	55
Lepisosteus osseus	Longnose Gar	Native	1	0.05	0	0.00	0	0.00	1
Notropis volucellus	Mimic Shiner	Native	6	0.30	115	5.75	1846	18.46	1967
Esox lucius	Northern Pike	Native	2	0.10	1	0.05	0	0.00	3
Lepomis gibbosus	Pumpkinseed	Native	31	1.55	31	1.55	5	0.05	67
Ambloplites rupestris	Rock Bass	Native	0	0.00	1	0.05	0	0.00	1
Neogobius melanostoma	Round Goby	Non-native	0	0.00	288	14.40	75	0.75	363
Notropis stramineus	Sand Shiner	Native	1	0.05	10	0.50	0	0.00	11
Moxostoma macrolepidotum	Shorthead Redhorse	Native	0	0.00	0	0.00	2	0.02	2
Macrhybopsis storeiana	Silver Chub	Native	0	0.00	3	0.15	13	0.13	16
Micropterus dolomieui	Smallmouth Bass	Native	2	0.10	0	0.00	0	0.00	2

Table 5: Catch summary for species captured during juvenile and adult fish sampling* in Maumee Bay, OH, 2017. *(continued)*

			Electrofishing		Paired Fyke Net		Bottom Trawl		
Scientific Name	Common Name	Status	Collected	CPUE (fish/hr)	Collected	CPUE (fish/set)	Collected	CPUE (fish/minute)	Total
Notropis hudsonius	Spottail Shiner	Native	0	0.00	428	21.40	31	0.31	459
Noturus gyrinus	Tadpole Madtom	Native	0	0.00	1	0.05	0	0.00	1
Percopsis omiscomaycus	Trout-Perch	Native	0	0.00	0	0.00	20	0.20	20
Sander vitreum	Walleye	Native	11	0.55	1	0.05	48	0.48	60
Morone chrysops	White Bass	Native	1	0.05	25	1.25	31	0.31	57
Morone americana	White Perch	Non-native	4	0.20	253	12.65	4208	42.08	4465
Catostomus commersonii	White Sucker	Native	0	0.00	0	0.00	1	0.01	1
Perca flavescens	Yellow Perch	Native	86	4.30	153	7.65	483	4.83	722

* Sampling effort for electrofishing was 3.3 hours, paired fyke nets was 20 overnight sets, and bottom trawling was 20 five minute tows.

Table 6: Catch summary for species captured during juvenile and adult fish sampling* in Lake St. Clair, MI, 2017.

			Paired Fyke Net		Bottom Trawl		
Scientific Name	Common Name	Status	Collected	CPUE (fish/set)	Collected	CPUE (fish/minute)	Total
Fundulus diaphanus	Banded Killifish	Native	11	0.73	2	0.03	13
Moxostoma duquesnii	Black Redhorse	Native	0	0.00	1	0.01	1
Notropis heterolepis	Blacknose Shiner	Native	1	0.07	0	0.00	1
Lepomis macrochirus	Bluegill	Native	520	34.67	3	0.04	523
Pimephales notatus	Bluntnose Minnow	Native	17	1.13	2	0.03	19
Labidesthes sicculus	Brook Silverside	Native	1	0.07	0	0.00	1
Ameiurus nebulosus	Brown Bullhead	Native	3	0.20	0	0.00	3
Notropis atherinoides	Emerald Shiner	Native	22	1.47	0	0.00	22
Etheostoma nigrum	Johnny Darter	Native	0	0.00	7	0.09	7
Micropterus salmoides	Largemouth Bass	Native	5	0.33	10	0.13	15
Percina caprodes	Logperch	Native	2	0.13	33	0.44	35
Notropis volucellus	Mimic Shiner	Native	2	0.13	14	0.19	16
Esox masquinongy	Muskellunge	Native	0	0.00	1	0.01	1
Lepomis gibbosus	Pumpkinseed	Native	8	0.53	0	0.00	8
Osmerus mordax	Rainbow Smelt	Non-native	0	0.00	2	0.03	2
Ambloplites rupestris	Rock Bass	Native	686	45.73	69	0.92	755
Neogobius melanostoma	Round Goby	Non-native	513	34.20	45	0.60	558
Micropterus dolomieui	Smallmouth Bass	Native	57	3.80	1	0.01	58
Notropis hudsonius	Spottail Shiner	Native	22	1.47	20	0.27	42
Percopsis omiscomaycus	Trout-Perch	Native	0	0.00	1	0.01	1
Proterorhinus semilunaris	Tubenose Goby	Non-native	18	1.20	0	0.00	18
Sander vitreum	Walleye	Native	0	0.00	1	0.01	1
Catostomus commersonii	White Sucker	Native	0	0.00	1	0.01	1

Table 6: Catch summary for species captured during juvenile and adult fish sampling* in Lake St. Clair, MI, 2017. *(continued)*

			Paired Fyke Net		Bottom Trawl		
Scientific Name	Common Name	Status	Collected	CPUE (fish/set)	Collected	CPUE (fish/minute)	Total
Ameiurus natalis	Yellow Bullhead	Native	5	0.33	0	0.00	5
Perca flavescens	Yellow Perch	Native	608	40.53	1534	20.45	2142

* Sampling effort for paired fyke nets was 15 overnight sets, and bottom trawling was 15 five minute tows.