GLIC: Implementing Great Lakes Coastal Wetland Monitoring

Summary Report

2010 – 2016

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INTRODUCTION

This project began on 10 September 2010. Most subcontracts were signed and in place with collaborating universities by late December 2010 or early January 2011. This project had the primary objective of implementing a standardized basin-wide coastal wetland monitoring program that will be a powerful tool to inform decision-makers on coastal wetland conservation and restoration priorities throughout the Great Lakes basin. Project outcomes include 1) development of a database management system; 2) development of a standardized sample design with rotating panels of wetland sites to be sampled across years, accompanied by sampling protocols, QAPPs, and other methods documents; and 3) development of background documents on the indicators. All of these objectives have been met.

During our first year we developed our Quality Assurance Project Plan (signed March 21, 2011), created a site selection mechanism and systems, selected our sites, and began the first year of wetland sampling, which began in late April/early May and continued through mid-September, 2011. Crews then successfully entered the field data into the data management system that we created, and completed all quality control procedures. We also began the tradition of having all primary project personnel meet in January or February each year to work through methods and details of all aspects of the project. During the first year, crews successfully sampled 176 sites using crew members that had completed extensive training sessions and passed all training requirements, including field sampling and identification tests.

During the next 4 years we successfully continued the wetland sampling that we implemented our first year. We conducted extensive reviews of our QAPP each year and revised the document several times to improve its clarity and to ensure that it accurately reflected our field and laboratory protocols. By the second year we were able to program our data management system to automatically calculate many of our metrics and some of the IBIs. Project PIs are continuing to refine metrics and calibrate them for use in Great Lakes coastal wetlands. By the end of our fifth year we had expanded the IBIs to all taxa types.

PROJECT ORGANIZATION

Figure 1 shows our project organization.

Please note that since our project started we have had two changes in primary personnel (both approved by US EPA). Ryan Archer of Bird Studies Canada was replaced by Doug Tozer. At the Michigan Department of Environmental Quality, Peg Bostwick retired and was replaced by Anne Hokanson (now Garwood). Matt Cooper has been awarded his doctoral degree and has taken a position with Northland College in Ashland, WI, but he continues to hold the same roles on the project as he did previously.

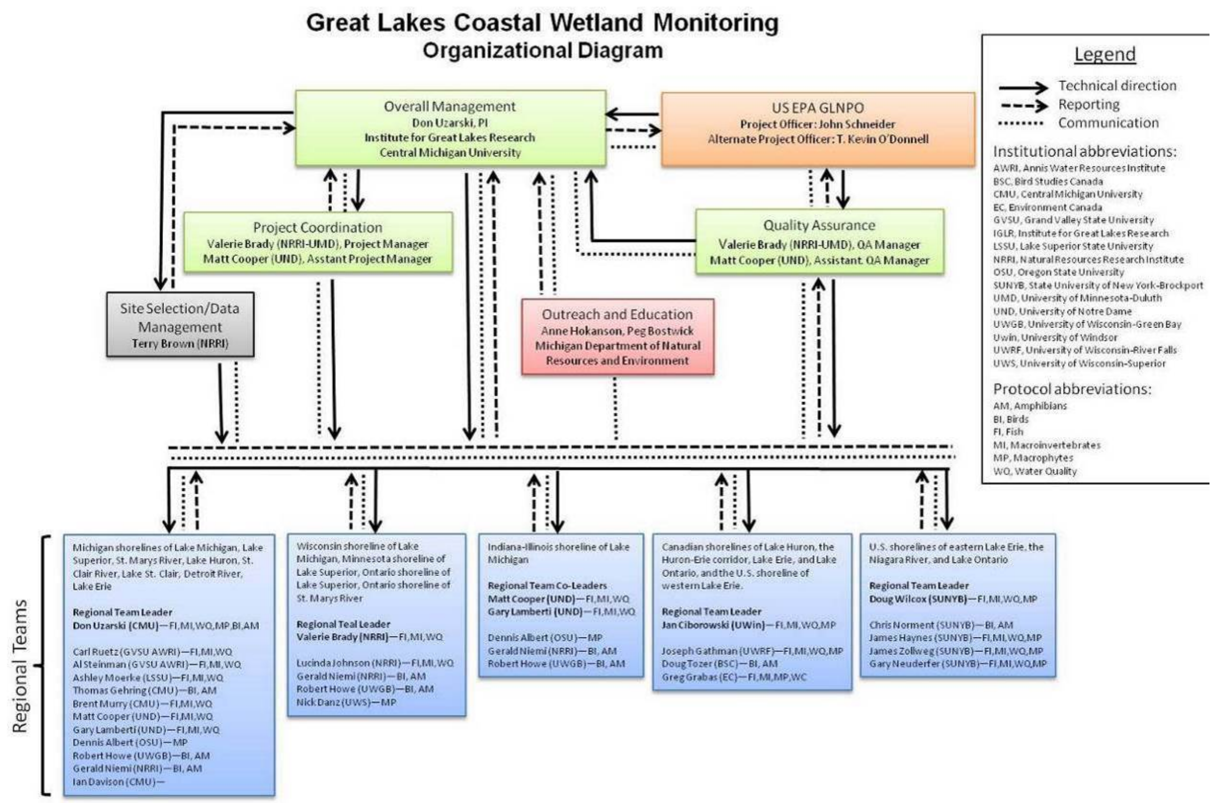

Figure 1. Organizational chart for the project showing lines of technical direction, reporting, and communication separately.

SITE SELECTION

Original data on Great Lakes coastal wetland locations

The GIS coverage used was a product of the Great Lakes Coastal Wetlands Consortium (GLCWC) and was downloaded from http://www.glc.org/wetlands/data/inventory/glcwc_cwi_polygon.zip on December 6, 2010. See http://www.glc.org/wetlands/inventory.html for details.

Site Selection Tool, completed in 2011, minor updates in 2012 and 2013

Background
In 2011, a web-based database application was developed to facilitate site identification, stratified random selection, and field crew coordination for the project. This database is housed at NRRI and backed up routinely. It is also password-protected. Using this database, potential wetland polygons were reviewed by PIs and those that were greater than four ha., had herbaceous vegetation, and had a lake connection were placed into the site selection random sampling rotation (Table 1). See the QAPP for a thorough description of site selection criteria.

Table 1. Preliminary counts, areas, and proportions of the 1014 Great Lakes coastal wetlands deemed sampleable following Great Lakes Coastal Wetland Consortium protocols based on review of aerial photography. Area in hectares.

Country	Site count	Site percent	Site area	Area percent
Canada	386	38%	35,126	25%
US	628	62%	105,250	75%
Totals	**1014**		**140,376**	

Note that the actual number of sampleable wetlands will fluctuate year-to-year with lake level and continued human activity. Based on the number of wetlands that proved to be sampleable thus far, we expect that the total number of sampleable wetlands will be between 900 and 1000 in any given year.

The wetland coverage we are using shows quite a few more wetlands in the US than in Canada, with an even greater percent of US wetland area (Table 1). We speculate that this is partly due to poor representation of Georgian Bay (Lake Huron) wetlands in the sampleable wetland database. This area is also losing wetlands due to a combination of glacial rebound and topography that limits the potential for coastal wetlands to migrate downslope when water levels are relatively low. Another component of this US/CA discrepancy is the lack of coastal wetlands along the Canadian shoreline of Lake Superior due to the rugged topography and geology. A final possibility is unequal loss of wetlands due to anthropogenic causes between the two countries, but this has not been investigated.

Strata

Geomorphic classes
Geomorphic classes (riverine, barrier-protected, and lacustrine) were identified for each site in the original GLCWC dataset. Many wetlands inevitably combine aspects of multiple classes, with an exposed coastal region transitioning into protected backwaters bisected by riverine elements. Therefore, wetlands were classified according to their predominant geomorphology.

Regions
Existing ecoregions (Omernik 1987, Bailey and Cushwa 1981, CEC 1997) were examined for stratification of sites. None were found which stratified the Great Lakes' shoreline in a manner that captured a useful cross section of the physiographic gradients in the basin. To achieve the intended stratification of physiographic conditions, a simple regionalization dividing each lake into northern and southern components, with Lake Huron being split into three parts and Lake Superior being treated as a single region, was adopted (Figure 2). The north-south splitting of Lake Michigan is common to all major ecoregion systems (Omernik / Bailey / CEC).

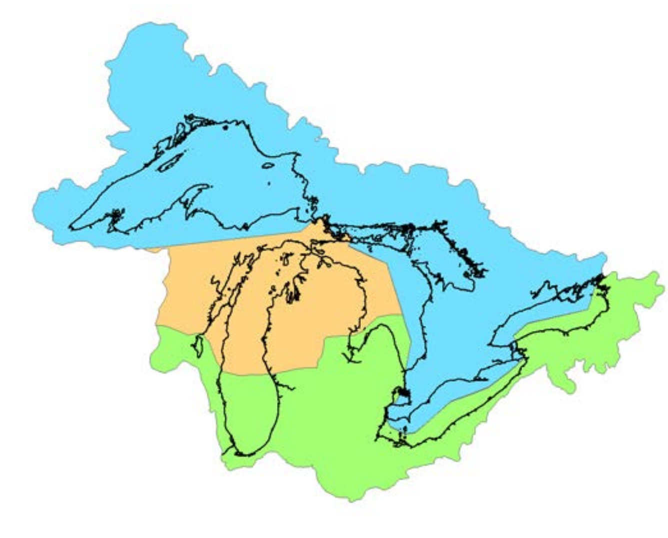

Figure 2. Divisions of lakes into regions. Note that stratification is by region *and* lake, so northern Lake Erie is not in the same region as Lake Superior, etc.

Panelization

Randomization
The first step in randomization was the assignment of selected sites from each of the project's 30 strata (10 regions x 3 geomorphic classes) to a random year or panel in the five-year rotating panel. Because the number of sites in some strata was quite low (in a few cases less than 5, more in the 5-20 range), simple random assignment would not produce the desired even distribution of sites within each strata over time. Instead it was necessary to assign the first fifth of the sites within a stratum, defined by their pre-defined random ordering, to one year, and the next fifth to another year, etc.

In 2012, sites previously assigned to panels for sampling were assigned to sub-panels for re-sampling. The project design's five year rotation with a 10% re-sampling rate requires five panels, *A*-*E*, and ten sub-panels, *a*-*j*. If 10% of each panel's sites were simply randomly assigned to sub-panels in order *a*-*j*, sub-panel *j* would have a low count relative to other sub-panels. To avoid this, the order of sub-panels was randomized for each panel during site-to-sub-panel assignment, as can be seen in the random distribution of the '20' and '21' values in Table 2.

For the first five-year cycle, sub-panel *a* will be re-sampled in each following year, so the 20 sites in sub-panel *a* of panel *A* were candidates for re-sampling in 2012. The 20 sites in sub-panel *a* of panel *B* were candidates for re-sampling in 2013, and so on. In 2016, when panel *A* is being sampled for the second time, the 21 sites in sub-panel *a* of panel *E* will be candidates for re-sampling, and in 2017, when panel *B* is being sampled for the second time, the 21 sites in sub-panel *b* of panel *A* will be candidates for re-sampling.

Table 2. Sub-panel re-sampling, showing year of re-sampling for sub-panels *a*-*c*.

	Subpanel										
Panel	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**TOTAL**
A: 2011 2016 2021	20/2012	21/2017	21/2022	20	21	20	21	21	21	21	207
B: 2012 2017 2022	20/2013	20/2018	20/2023	21	20	21	21	20	21	21	205
C: 2013 2018 2023	21/2014	21/2019	21/2024	21	21	20	21	21	21	21	209
D: 2014 2019 2024	22/2015	21/2020	21/2025	21	21	21	21	21	21	21	211
E: 2015 2020 2025	21/2016	20/2021	21/2026	21	21	21	20	21	21	21	208

Workflow states

Each site was assigned a particular 'workflow' status. During the field season, sites selected for sampling in the current year will move through a series of sampling states in a logical order, as shown in Table 3. The *data_level* field is used for checking that all data have been received and their QC status. Users set the workflow state for sites in the web tool, although some states can also be updated by querying the various data entry databases.

Team assignment

With sites assigned to years and randomly ordered within years, specific sites were then assigned to specific teams. Sites were assigned to teams initially based on expected zones of logistic practicality, and the interface described in the 'Site Status' section was used to exchange sites between teams for efficiency and to better assure that distribution of effort matches each team's sampling capacity.

Table 3. Workflow states for sites listed in the Site Status table within the web-based site selection system housed at NRRI. This system tracks site status for all taxonomic groups and teams for all sites to be sampled in any given year. Values have the following meanings: -1: site will not generate data, 0: site may or may not generate data, 1: site should generate data, 2: data received, 3: data QC'd.

Name	Description	Data_level
too many	Too far down randomly-ordered list, beyond sampling capacity for crews.	-1
Not sampling BM	Benchmark site that will not be sampled by a particular crew.	-1
listed	Place holder status; indicates status update needed.	0
web reject	Rejected based on regional knowledge or aerial imagery in web tool.	-1
will visit	Will visit with intent to sample.	0
could not reach	Proved impossible to access.	-1
visit reject	Visited in field, and rejected (no lake influence, etc.).	-1
will sample	Interim status indicating field visit confirmed sampleability, but sampling has not yet occurred.	1
sampled	Sampled, field work done.	1
entered	Data entered into database system.	2
checked	Data in database system QC-checked.	3

Field maps

Multi-page PDF maps are generated for each site for field crews each year. The first page depicts the site using aerial imagery and a road overlay with the wetland site polygon boundary (using the polygons from the original GLCWC file, as modified by PIs in a few cases). The image also shows the location of the waypoint provided for navigation to the site via GPS. The second page indicates the site location on a road map at local and regional scales. The remaining pages list information from the database for the site, including site tags, team assignments, and the history of comments made about the site, including information from previous field crew visits and notes about how to access each site.

Browse map

The *browse map* feature allows the user to see sites in context with other sites, overlaid on either Google Maps or Bing Maps road or aerial imagery. Boat ramp locations are also shown when available. The *browse map* provides tools for measuring linear distance and area. When a site is clicked, the tool displays information about the site, the tags and comments applied to it, the original GLCWC data, links for the next and previous site (see *Shoreline ordering* and *Filter sites*), and a link to edit the site in the site editor.

TRAINING

All personnel responsible for sampling invertebrates, fish, macrophytes, birds, amphibians, and water quality received training and were certified prior to sampling in 2011. During that first year, teams of experienced trainers held training workshops at several locations across the Great Lakes basin to ensure that all PIs and crews were trained in Coastal Wetland Monitoring methods. After that first year, field crew training was done by each PI and/or crew chief at each regional location. All crew members had to pass all training tests each year, and PIs conducted mid-season QC checks with all crews each year. Trainers were available each season if a crew had substantial turnover and training assistance was needed. In addition, the trainers were always available via phone and email to answer any questions that arose during training sessions or during the field season.

The following is a synopsis of the training conducted each spring: Each PI or field crew chief trained all field personnel on meeting the data quality objectives for each element of the project; this included reviewing the most current version of the QAPP, covering site verification procedures, providing hands-on training for each sampling protocol, and reviewing record-keeping and archiving requirements, data auditing procedures, and certification exams for each sampling protocol. All field crew members were required to pass all training certifications before they were allowed to work unsupervised. Those who did not pass all training aspects were only allowed to work under the supervision of a crew leader who had passed all training certifications.

Training for bird and amphibian field crews included tests on amphibian calls, bird vocalizations, and bird visual identification. These tests are based on an online system established at the University of Wisconsin, Green Bay – see http://www.birdercertification.org/GreatLakesCoastal. In addition, individuals were tested for proficiency in completing field sheets, and audio testing was done to ensure their hearing was within the normal ranges. Field training was also completed to ensure guidelines in the QAPP were followed: rules for site verification, safety issues including caution regarding insects (e.g., tick-borne diseases), GPS and compass use, and record keeping.

Fish, macroinvertebrate, and water quality crews were trained on field and laboratory protocols. Field training included selecting appropriate sampling locations, setting fyke nets, identifying fish, sampling and sorting invertebrates, and collecting water quality and habitat covariate data. Laboratory training included preparing water samples, titrating for alkalinity, and filtering for chlorophyll. Other training included GPS use, safety and boating issues, field sheet completion, and GPS and records uploading. All crew members were required to be certified in each respective protocol prior to working independently.

Vegetation crew training also included both field and laboratory components. Crews were trained in field sheet completion, transect and point location and sampling, GPS use, and plant curation. Plant identification was tested following phenology through the first part of the field season. All crew members had to be certified in all required aspects of sampling before starting in the field, unless supervised.

Training on data entry and data QC was provided by Valerie Brady and Terry Brown through a series of conference calls/webinars during the late summer, fall, and winter of 2011. All co-PIs and crew leaders responsible for data entry participated in these training sessions and each regional laboratory successfully uploaded data each year. The re-created data entry system is very similar to the original system and crews had no trouble with data entry into the new system.

Certification

To be certified in a given protocol, individuals must pass a practical exam. Certification exams were conducted in the field in most cases, either during training workshops or during site visits early in the season. When necessary, exams were supplemented with photographs (for fish and vegetation) or audio recordings (for bird and amphibian calls). Passing a given exam certified the individual to perform the respective sampling protocol(s). Since not every individual was responsible for conducting every sampling protocol, crew members were only tested on the protocols for which they were responsible. Personnel who were not certified (e.g., part-time technicians, new students, volunteers) were not be allowed to work independently nor to do any taxonomic identification except under the direct supervision of certified staff members. Certification criteria are listed in the project QAPP. For some criteria, demonstrated proficiency during field training workshops or during site visits was considered adequate for certification. Training and certification records for all participants were collected by regional team leaders and copied to Drs. Brady and Cooper (QC managers) and Uzarski (lead PI). Note that the training and certification procedures explained here are separate from the QA/QC evaluations explained in the following section. However, failure to meet project QA/QC standards required participants to be re-trained and re-certified.

Documentation and Record

All site selection and sampling decisions and comments are archived in the site selection system created by Dr. Terry Brown (see “site selection”). These include comments and revisions made during the QC oversight process.

Regional team leaders archived copies of the testing and certification records of all field crew members. Summaries of these records were also archived with the lead PI (Uzarski), and the QA managers (Brady and Cooper).

Web-based Data Entry System

We began this project using a web-based data entry system that was developed in 2011 to collect field and laboratory data. The open source Django web application framework was used with the open source postgresql database as the storage back end, with a separate application for each taxonomic group. Forms for data entry were generated automatically based on an XML document describing the data structure of each taxonomic group's observations. Each data entry web form was password-protected, with passwords assigned and tracked for each individual.

Features of note include:

- fine-grained access control with individual user logins, updated every winter;
- numerous validation rules of varying complexity to avoid incorrect or duplicate data entry;
- custom form elements to mirror field sheets, e.g. the vegetation transects data grid; this makes data entry more efficient and minimizes data entry errors;
- domain-specific utilities, such as generation of fish length records based on fish count records;
- dual-entry inconsistency highlighting for groups using dual-entry for quality assurance;
- user interface support for the highly hierarchical data structures present in some project data.

EPA GLNPO has been given access to the data retrieval system and data. The public, if they access this site, can see summaries of numbers of sites sampled by the various crews for the different taxonomic groups. Other features are only visible to those with a password.

The data download system has been expanded with the capability of serving static files as well as tabular data queried on demand for the database server. Static file serving is used to deliver data in Excel and Access-ready formats. These datasets are intended to give fine-grained access for data analysis by PIs. These files also provide a complete backup of the project data in a format that does not require the database server to be running to allow access.

We have also developed an interactive map available as a website that will allow users to visualize and download site level attributes such as IBI scores. This web-based tool requires no specialized software on the user's system. Tools for defining a user-specified area of interest will provide results in regional and local contexts. Authorized users (i.e., agency personnel and other managers) will be able to drill down to specific within-site information to determine what factors are driving an individual site's scores.

The above system was used for data entry through the data collected in the 2015 field season. Since then, we have switched over to an updated database and web interface developed for the project by LimnoTech, which will provide improved functionality and security. LimnoTech has also developed an updated interactive map for data visualization.

RESULTS-TO-DATE (2011-2015)

A total of 176 wetlands were sampled in 2011, with 206 sampled in 2012, 201 in 2013, 216 in 2014, and 211 in 2015, our 5th and final summer of sampling for the first round. Overall, 1010 Great Lakes coastal wetland sampling events were conducted in this five-year effort (Table 4). Note that this is not the same as the number of unique wetlands sampled because of temporal re-sampling events and benchmark sites that were sampled in more than one year.

In all years, more wetlands were sampled on the US side due to the uneven distribution of wetlands between the two countries. The wetlands on the US side also tended to be larger (see area percentages, Table 4). When compared to the total number of wetlands targeted to be sampled by this project (Table 1), we achieved our goal of sampling 20% of US wetlands per year, both by count and by area. However, 66% of total sites sampled were US coastal wetlands, with 80% of the wetland area sampled being on the US side. Overall, not yet correcting for sites that have been sampled more than once, we sampled about 80% of US coastal wetlands by count and by area. With respect to the entire Great Lakes, the project sampled roughly 100% of the large and safely accessible coastal wetlands by both count and area.

Teams were able to sample more sites in 2014 and 2015 than previous years due to higher water levels on Lakes Michigan and Huron, which allowed crews to access sites and areas that had been dry or inaccessible in previous years. This highlights the difficulty of precisely determining the number of sampleable Great Lakes coastal wetlands in any given year.

Table 4. Counts, areas, and proportions of the 1010 Great Lakes coastal wetlands sampled from 2011 through 2015 by the GLIC: Coastal Wetland Monitoring Project. Percentages are of overall total sampled wetlands. Area in hectares.

Country	Site count	Site %	Site area	Area %
Canada				
2011	50	28%	3,303	13%
2012	82	40%	7,917	27%
2013	71	35%	7,125	27%
2014	72	33%	6,781	20%
2015	77	36%	10,011	27%
CA total	**352**	**35%**	**35,137**	**23%**
US				
2011	126	72%	22,008	87%
2012	124	60%	21,845	73%
2013	130	65%	18,939	73%
2014	144	67%	26,836	80%
2015	134	64%	26,681	73%
US total	**658**	**65%**	**116,309**	**77%**
Overall Totals	**1010**		**151,446**	

The sites sampled from 2011 to 2015 are shown in Figure 3, color coded by the taxonomic groups sampled at each site. Many sites were sampled for all taxonomic groups. Sites not sampled for birds and amphibians typically were sites that were impossible to access safely, and often related to private property access issues. Most bird and amphibian crews do not operate from boats since they need to arrive at sites in the dark or stay until well after dark. There were also a number of sites sampled only by bird and amphibian crews because these crews were able to complete their site sampling more quickly and thus had the capacity to sample more sites than did the fish, macroinvertebrate, and vegetation crews.

Wetland types are not distributed evenly across the Great Lakes due to fetch, topography, and geology. Lacustrine wetlands occur in more sheltered areas of the Great Lakes within large bays or adjacent to islands. Barrier-protected wetlands occur along harsher stretches of coastline, particularly in sandy areas, although this is not always the case. Riverine wetlands are somewhat more evenly distributed around the Great Lakes. Low water levels in 2011-2013 and much higher water levels in 2014 and 2015 require that indicators be relatively robust to Great Lakes water level variations.

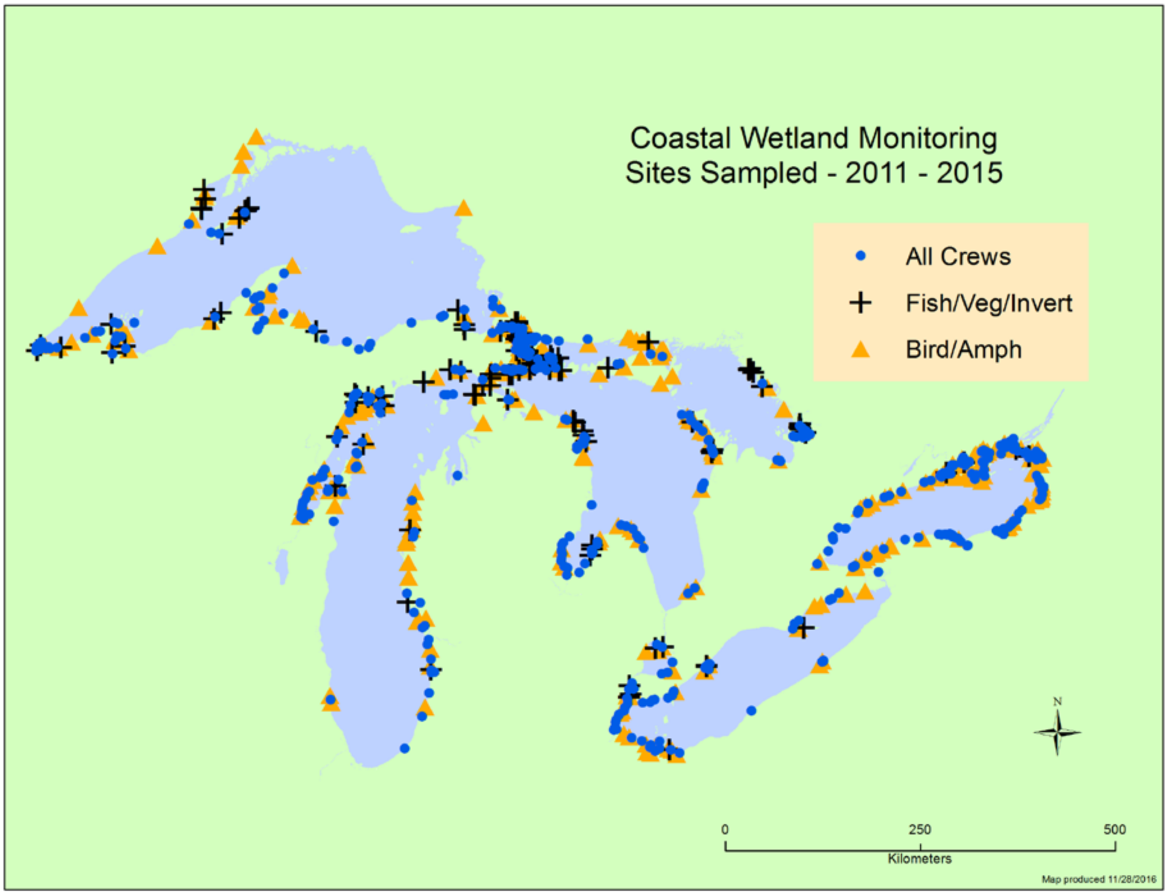

Figure 3. Locations of Great Lakes coastal wetlands sampled in 2011 - 2015, color-coded by taxonomic groups. Sites assigned only to bird and amphibian crews (due to their greater sampling capacity) are shown with a gold triangle.

Benchmark sites are sites that were either added to the overall site list and would not have been sampled as part of the random selection process, or are sites that were considered a reference of some type and were sampled more frequently. Sites that would not have been sampled typically were too small, disconnected from lake influence, or were not a wetland at the time, and thus did not fit the protocol. These sites were added back to the sampling list by request of researchers, agencies, or others who have specific interest in the sites. Many of these sites are scheduled for restoration, and the groups who will be restoring them need baseline data against which to determine restoration success. Each year, Coastal Wetland Monitoring (CWM) researchers received many requests to provide baseline data for restoration work; this occurred at a frequency great enough for us to have difficulty accommodating the extra effort.

As of 2015, we have 60 sites designated as "benchmark." Of these, 20 (30%) were to evaluate restoration efforts and 17 (28%) served as reference sites for their area or for nearby restoration sites. The rest were more intensive monitoring sites at which the extra data will help provide long-term context and better ecological understanding of coastal wetlands. Almost all benchmark sites were in the US.

Determining whether benchmark sites would have been sampled at some point as part of the random site selection process is somewhat difficult because some of the exclusion conditions are not easy to assess without site visits. Our best estimate is that approximately 60% of the 17 benchmark sites from 2011 would have been sampled at some point, but they were marked "benchmark" to either sample them sooner (to get ahead of restoration work for baseline sampling) or so that they could be sampled more frequently. Thus, about 40% of 2011 benchmark sites were either added new because they are not (yet) wetlands, are small, or were missed in the wetland coverage, or would have been excluded for lack of connectivity. This percentage decreased in 2012, with only 20% of benchmark sites being sites that were not already on the list of wetlands scheduled to be sampled. In 2013, 30% of benchmark sites were not on the list of random sites to be sampled by CWM researchers in any year, and most were not on the list for the year 2013. For 2014, 26% of benchmark sites were not on the list of sampleable sites, and only 20% of these benchmark sites would have been sampled in 2014. There were a number of benchmark sites that were sampled every year or every other year to collect extra data on these locations. Thus, by 2013 we were adding relatively few new sites as benchmarks each year. These tended to be sites that were very degraded former wetlands that no longer appear on any wetland coverage, but for which restoration is a goal.

We can now compile good statistics on Great Lakes coastal wetlands because we have sampled nearly 100% of the medium and large, hydrologically-connected coastal wetlands on the Great Lakes. Wetlands contained approximately 25 bird species on average; some sampled benchmark sites had as few as 1 species, but richness at high quality sites was as great as 60 bird species (Table 5). There are many fewer calling amphibian species in the Great Lakes (8 total), and coastal wetlands averaged about 4 species per wetland, with some benchmark wetlands containing no calling amphibians (Table 5). However, there were wetlands where all 8 calling amphibian species were heard over the three sampling dates.

Table 5. Bird and calling amphibian species in wetlands; summary statistics by country. Data from 2011 through 2015.

Country	Site count	Mean	Max	Min	St. Dev.
Birds					
Can.	309	28.5	58	8	10.0
U.S.	573	22.1	60	1	11.5
Amphibians					
Can.	310	4.5	8	0	1.8
U.S.	543	3.7	8	0	1.5

Bird and amphibian data in Great Lakes coastal wetlands by lake (Table 6) shows that wetlands on most lakes averaged around 25 bird species, with Lake Ontario coastal wetlands averaging the fewest species. The greatest number of bird species at a wetland occurred on Lake Michigan, with Lake Huron a close second, followed by Erie and Superior. Lake Ontario had the fewest maximum species at a wetland. These data include the benchmark sites, many of which are in need of restoration, so the minimum number of species is quite low (as few as a single species) for some of these wetlands.

Calling amphibian species counts show less variability among lakes simply because fewer of these species occur in the Great Lakes. Wetlands averaged three to nearly five calling amphibian species regardless of lake (Table 6). Similarly, there was little variability by lake in maximum or minimum numbers of species. At some benchmark sites and in cold springs no calling amphibians were detected.

Table 6. Bird and amphibian species found in Great Lakes coastal wetlands by lake. Mean, maximum, and minimum number of species per wetland for wetlands sampled from 2011 through 2015.

	Birds				**Calling amphibians**			
Lake	**Sites**	**Mean**	**Max**	**Min**	**Sites**	**Mean**	**Max**	**Min**
Erie	116	24.8	54	4	103	3.4	7	0
Huron	271	25.0	58	2	268	4.0	8	0
Michigan	146	23.8	60	1	135	3.6	7	0
Ontario	230	22.3	47	8	231	4.7	8	1
Superior	119	27.1	52	11	116	3.6	7	0

An average of 10 to about 13 fish species were collected in Canadian and US Great Lakes coastal wetlands, respectively (Table 7). Again, these data include sites in need of restoration, and some had very few species. On the other hand, the wetlands with the highest richness had as many as 23 (CA) or 28 (US) fish species. The average number of non-native fish species per wetland was approximately one, though some wetlands had as many as 5 (US). An encouraging sign is that there are wetlands in which no non-native fish species were caught in fyke nets, although some non-native fish are adept at net avoidance (e.g., common carp).

Table 7. Total fish species in wetlands, and non-native species; summary statistics by country for sites sampled from 2011 through 2015.

Country	Sites	Mean	Max	Min	St. Dev.
Overall					
Can.	156	10.0	23	2	3.9
U.S.	365	13.3	28	2	5.2
Non-natives					
Can.	156	0.7	3	0	0.7
U.S.	365	0.7	5	0	0.9

Combining 2011 through 2015 data, there were no non-native fish species caught at 48% of the Great Lakes coastal wetlands sampled, but 37% had one non-native species (Figure 4). More than one non-native species was captured at many fewer sites. It is important to note that the sampling effort at sites was limited to one night using passive capture nets, so these numbers are likely quite conservative, and wetlands where we did not catch non-native fish may actually harbor them.

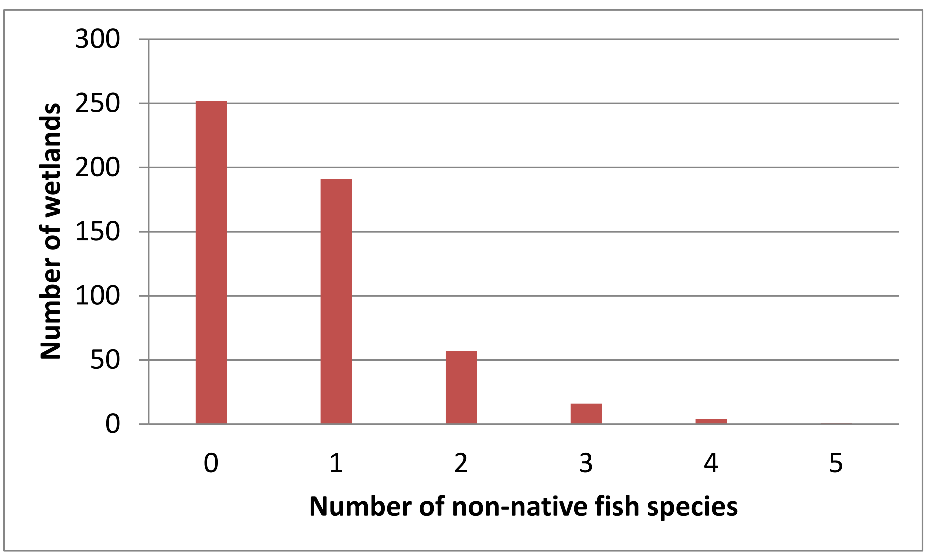

Figure 4. Number of Great Lakes coastal wetlands containing non-native fish species. Data from 2011 through 2015.

Total fish species did not differ greatly by lake, averaging 12-14 species per wetland (Table 8). Lake Ontario wetlands had the lowest maximum number of species, with the other lakes all having similar maximums of 27-28 species. Since sites in need of restoration are included in this assessment, some of these sites had very few fish species, as low as two. Lake Huron wetlands averaged the lowest mean number of non-native fish taxa. All other lakes had a similar average number of non-native fish species per wetland, about 1. Having very few or no non-native fish is a positive, however, and all lakes had some wetlands in which we caught no non-native fish. This result does not necessarily mean that these wetlands are free of non-natives, unfortunately. Our single-night net sets do not catch all fish species in wetlands, and some species are quite adept at avoiding passive capture gear. For example, common carp are known to avoid fyke nets. When interpreting fish data it is important to keep in mind the well-documented biases associated with each type of sampling gear. For example, active sampling gears (e.g., electrofishing) are better at capturing large active fish, but perform poorly at capturing smaller fish, forage fish, and young fish that are sampled well by our passive gear.

Table 8. Fish total species and non-native species found in Great Lakes coastal wetlands by lake. Mean, maximum, and minimum number of species per wetland. Data from 2011 through 2015.

		Fish (Total)			**Non-native**		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	66	12.2	27	2	1.1	4	0
Huron	180	11.5	27	2	0.4	2	0
Michigan	75	13.1	28	5	0.8	4	0
Ontario	135	12.3	23	4	0.8	3	0
Superior	65	14.1	28	3	0.9	5	0

The average number of macroinvertebrate taxa (taxa richness) per site was about 40 (Table 9), but some wetlands had more than twice this number. Sites scheduled for restoration and other taxonomically poor wetlands had fewer taxa, as low as 13 in Canada, but we now have restoration sites in the US in which no wetland taxa were found using our sampling techniques (Tables 9 and 10). On a more positive note, the average number of non-native invertebrate taxa in coastal wetlands was less than 1, with a maximum of no more than 5 taxa (Table 9). Note that our one-time sampling may not be capturing all of the non-native taxa at wetland sites. In addition, some non-native macroinvertebrates are quite cryptic, resembling native taxa, and may not yet be recognized as invading the Great Lakes.

Table 9. Total macroinvertebrate taxa in Great Lakes coastal wetlands, and non-native species; summary statistics by country. Data from 2011 through 2015.

Country	Sites	Mean	Max	Min	St. Dev.
Overall					
Can.	189	40.0	76	13	12.5
U.S.	413	39.3	85	0	15.6
Non-natives					
Can.	189	0.9	3	0	0.9
U.S.	413	0.7	5	0	1.0

There is some variability among lakes in the mean number of macroinvertebrate taxa per wetland. There is also an effect of the benchmark sites in these summaries. We have found an average of about 35-45 macroinvertebrate taxa in wetlands, with lakes Ontario, Michigan, and Erie having lower averages than lakes Huron and Superior (Table 10). The maximum number of invertebrate taxa was higher in lakes Huron and Michigan wetlands (>80) than for the most invertebrate-rich wetlands in the other lakes, which have a maximum of 60-70 taxa. Wetlands with the fewest taxa are sites in need of restoration and some have no macroinvertebrate taxa found at all. Patterns are likely being driven by differences in habitat complexity, which may in part be due to the loss of wetland habitats on lakes Erie and Ontario from diking (Erie) and water level control (Ontario). This has been documented in numerous peer-reviewed publications. There was little variability among lakes in non-native taxa occurrence, although Erie and Huron had wetlands with 4-5 non-native taxa. In each lake there were some wetlands in which we found no non-native macroinvertebrates. As noted above, however, this does not necessarily mean that these sites do not contain non-native macroinvertebrates.

Table 10. Macroinvertebrate total taxa and non-native species found in Great Lakes coastal wetlands by lake. Mean, maximum, and minimum number of taxa per wetland. Data from wetlands sampled in 2011 through 2015.

		Macroinvertebrates (Total)			Non-native		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	72	36.3	70	12	1.2	4	0
Huron	220	43.5	81	13	0.8	5	0
Michigan	86	37.0	85	0	0.7	3	0
Ontario	141	34.6	63	12	0.9	3	0
Superior	79	42.9	69	0	0.1	2	0

In 2014 we realized that we are finding some non-native, invasive species in significantly more locations around the Great Lakes than are being reported on nonindigenous species tracking websites such as the USGS's Nonindigenous Aquatic Species (NAS) website (http://nas.er.usgs.gov/). Locations of aquatic macroinvertebrates are particularly under-reported. The best example of the difference is shown in Figures 5 and 6 for the faucet snail, *Bithynia tentaculata*. Figure 5 shows the range portrayed on the USGS website for this snail before we reported our findings. Figure 6 shows the locations where our crew found this snail. Finally, Figure 7 shows the USGS website map after it was updated with our crews' reported findings.

The faucet snail is of particular interest to USFWS and others because it carries parasites that can cause disease and die-offs of waterfowl. Because of this, we produced numerous press releases reporting our findings (collaborating universities produced their own press releases). The Associated Press ran the story and about 40 articles were generated in the news that we are aware of. See Appendix for a mock-up of our press release and a list of articles that ran based on this press release.

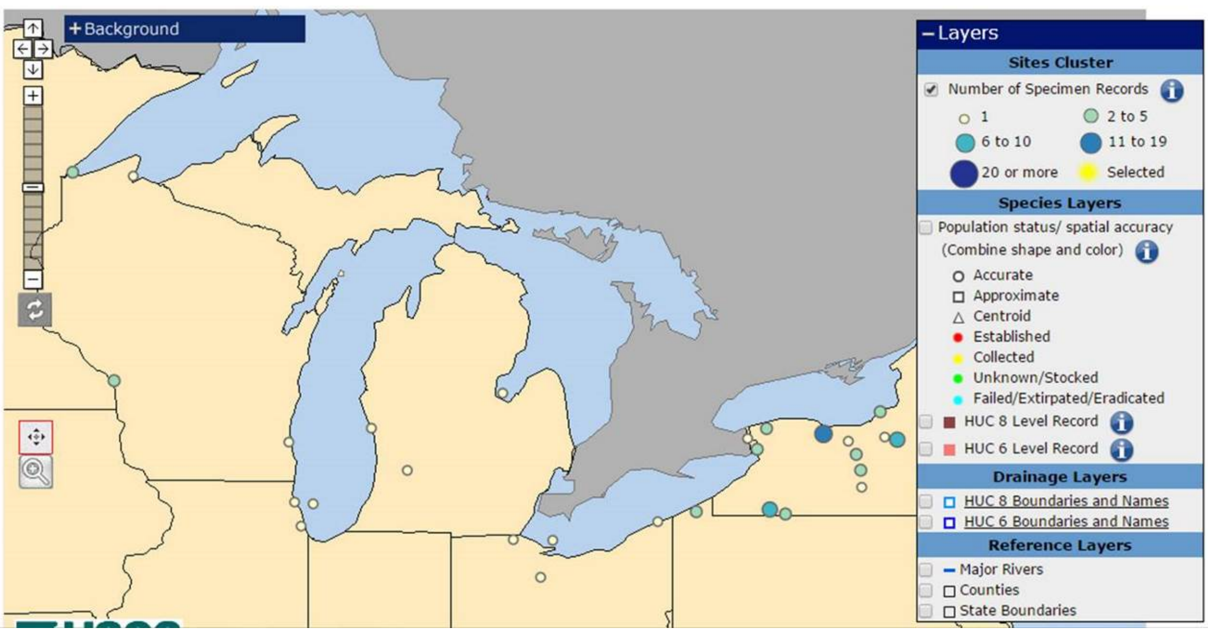

Figure 5. Locations of *Bithynia tentaculata* in USGS NAS website PRIOR to our project providing additional locations where they were collected.

One reason that we were able to increase the geographic range and total number of known locations occupied by faucet snails is the limited number of ecological surveys occurring in the Great Lakes coastal zone. Furthermore, those surveys that do exist tend to be at a much smaller scale than ours and sample wetlands using methods that do not detect invasive species with the precision of our program.

In collaboration with the Great Lakes Environmental Indicators project and researchers at the USEPA Mid-Continent Ecology Division in Duluth and at the University of Wisconsin Superior, a note was published in the Journal of Great Lakes Research about the spread of *Bithynia* in Lake Superior (Trebitz et al. 2015).

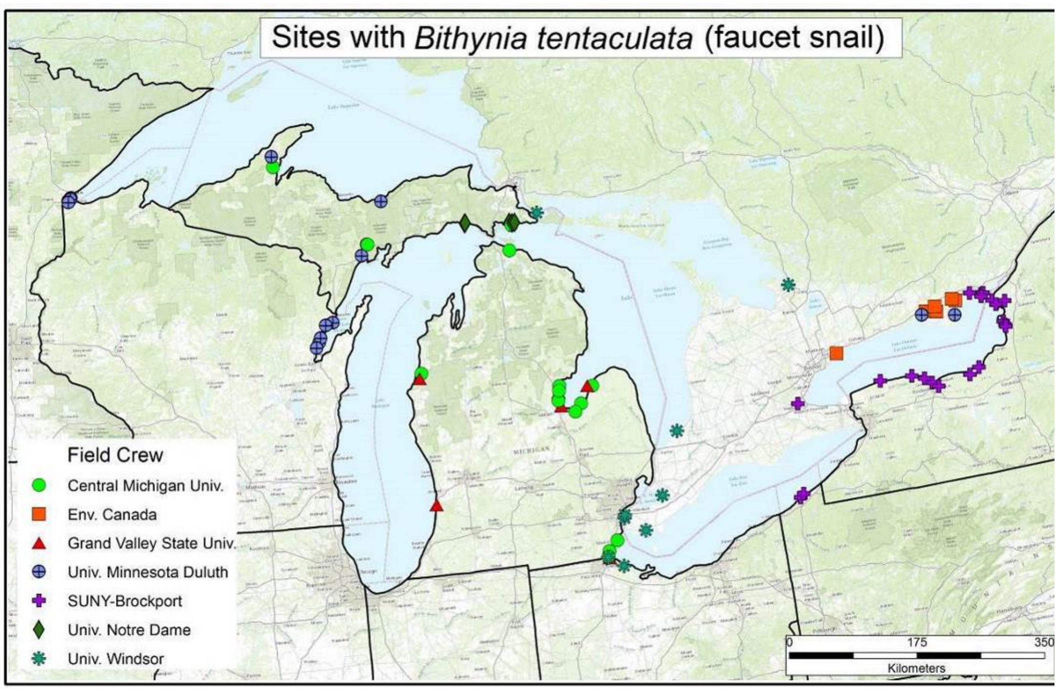

Figure 6. Locations of *Bithynia tentaculata* found by CWM crews, 2011 - 2013.

We also provided USGS with locations of other non-native macroinvertebrates and fish. The invasive macrophyte information had previously been provided to websites that track these locations, and reported to groups working on early detection and eradication.

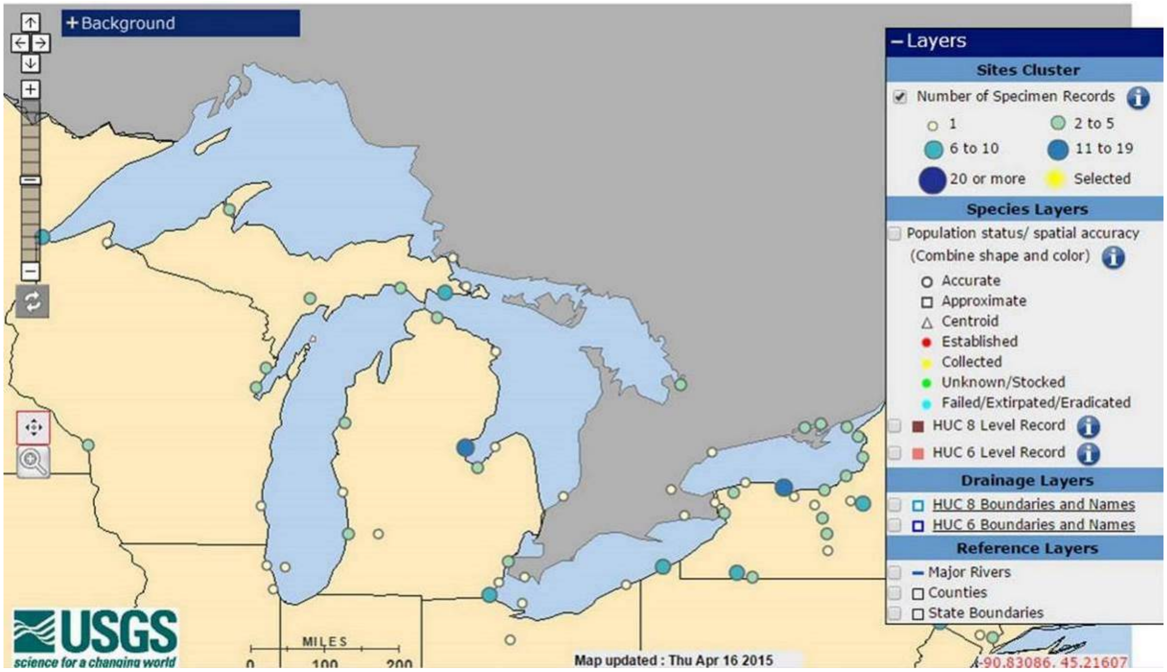

Figure 7. Locations of *Bithynia tentaculata* in USGS NAS website AFTER our project provided additional locations where they were collected; compare to Figure 7.

On average, there were approximately 45 wetland plant (macrophyte) species per wetland (Table 11), but the maximum number has risen to 100 species at a very diverse site. Some sites were quite depauperate in plant taxa (some having almost none), particularly in highly impacted areas that were no longer wetlands but were sampled because they are designated for restoration.

Invasive vegetation is commonly found in Great Lakes coastal wetlands. Those that we sampled averaged 3-4 invasive species (Table 11). Note that species classified as "invasives" are often non-native as well, but do not have to be to receive that designation. For example, some cattail (*Typha*) species are considered invasive although they are native taxa. Some wetlands contained as many as 9 invasive macrophyte species, but there were wetlands in which no invasive plant species were found. It is unlikely that our sampling strategy would miss significant invasive macrophytes in a wetland. However, small patches of cryptic or small-stature non-natives could be missed. Invasive species are a particularly important issue for restoration work. Restoration groups often struggle to restore wetland sites without having invasive species become dominant.

Table 11. Total macrophyte species in Great Lakes coastal wetlands, invasive species and US at-risk species; summary statistics by country. Data from 2011 through 2015.

Country	Site count	Mean	Max	Min	St. Dev.
Overall					
Can.	206	45.3	87	7	16.0
U.S.	453	44.0	100	1	17.4
Invasives					
Can.	206	3.7	8	0	2.0
U.S.	453	3.3	9	0	2.1
At risk					
U.S.	453	0.1	2	0	0.32

We had trustworthy information about at-risk wetland vegetation for only the US side of the Great Lakes. At-risk species (federal and state-designated) were not commonly encountered during sampling, as can be seen in Table 11. The average number of at-risk species per site was nearly zero, with most sites having no at-risk species; the maximum found at a site was only two species. This may be partly due to the sampling methods, which did not include a random walk through all habitats to search for at-risk species.

Lake Huron wetlands had the greatest mean number of macrophyte species, with Lake Erie wetlands having much lower mean numbers of species than wetlands on the other Great Lakes (Table 12). Maximum species richness in Lake Erie wetlands was lower than wetlands on the other Great Lakes, and even Lake Erie restoration sites had fewer minimum species. Average numbers of invasive species were highest in lakes Erie and Ontario and lowest in Lake Superior wetlands. Lake Superior had the lowest maximum number of invasive macrophytes in a wetland, with all the other lakes having about the same maximum number (5-9 species). Lake Ontario was the only lake without a single wetland that was free of non-native species.

Table 12. Macrophyte total species and invasive species found in Great Lakes coastal wetlands by lake. Mean, maximum, and minimum number of species per wetland. Data from 2011 through 2015.

		Macrophytes (Total)			Invasives		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	80	29.0	69	1	4.6	8	0
Huron	245	53.0	100	8	2.6	8	0
Michigan	97	45.4	83	4	3.3	7	0
Ontario	152	40.7	87	8	5.1	9	1
Superior	81	40.6	78	2	1.7	5	0

Our macrophyte data have reinforced our understanding of the numbers of coastal wetlands that contain invasive plant species (Figure 8). Only 9% of 631 sampled wetlands lacked invasive species, leaving 91% with at least one. Sites were most commonly invaded by 2 – 5 invasive plant species and 6% of sites contained 7 or more invasive species. Detection of invasive species is more likely for plants than for organisms that are difficult to collect such as fish and other mobile fauna, but we may have missed small patches of invasives in some wetlands.

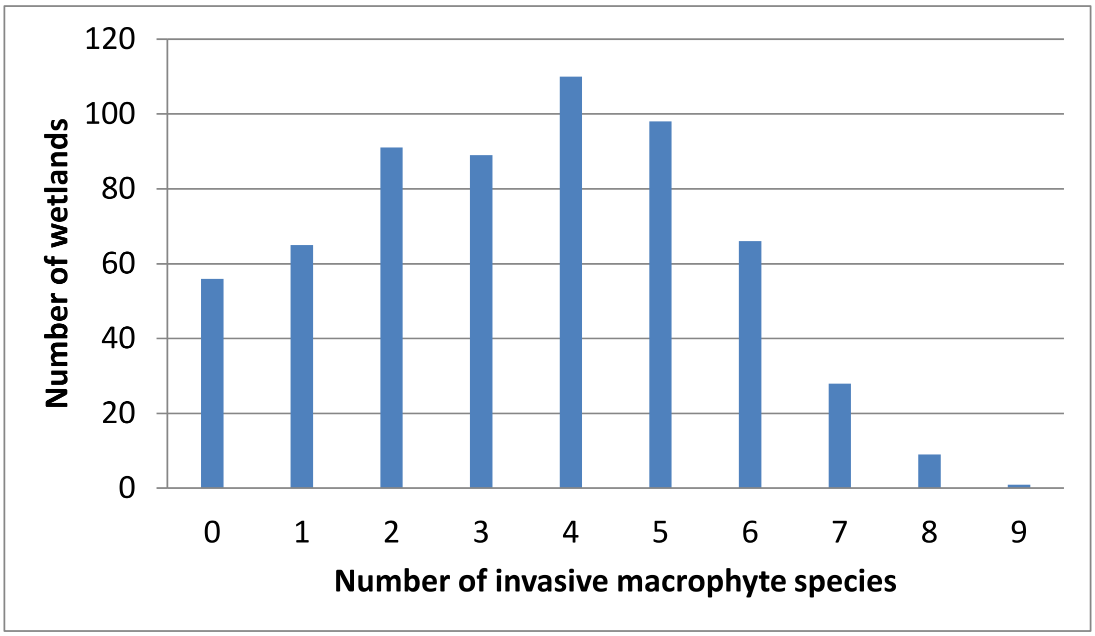

Figure 8. Number of Great Lakes coastal wetlands containing invasive plant species based on 2011 through 2015 data.

As an example for the state of Michigan, we also looked at wetlands with both invasive plants and plant species considered "at risk" (Figure 9). We found that there were a few wetlands at all levels of invasion that also had at-risk plant populations. This information will be useful to groups working to protect at-risk populations by identifying wetlands where invasive species threaten sensitive native species.

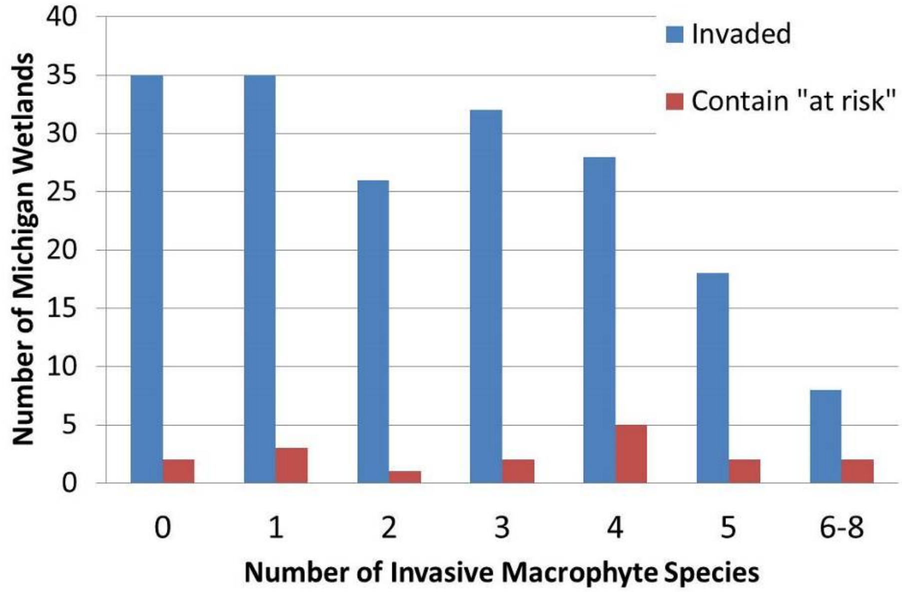

Figure 9. Number of state of Michigan Great Lakes coastal wetlands containing both invasive plant species and “at risk” plant species, based on 2011 through 2014 data.

We created a map of invasion status of Great Lakes coastal wetlands using all invasive species data we collected through 2014 for all taxonomic groups combined (Figure 10). Unfortunately, this shows that most sites have some level of invasion, even on Isle Royale. However, the more remote areas clearly had fewer invasives than the more populated areas and areas with relatively intense human use.

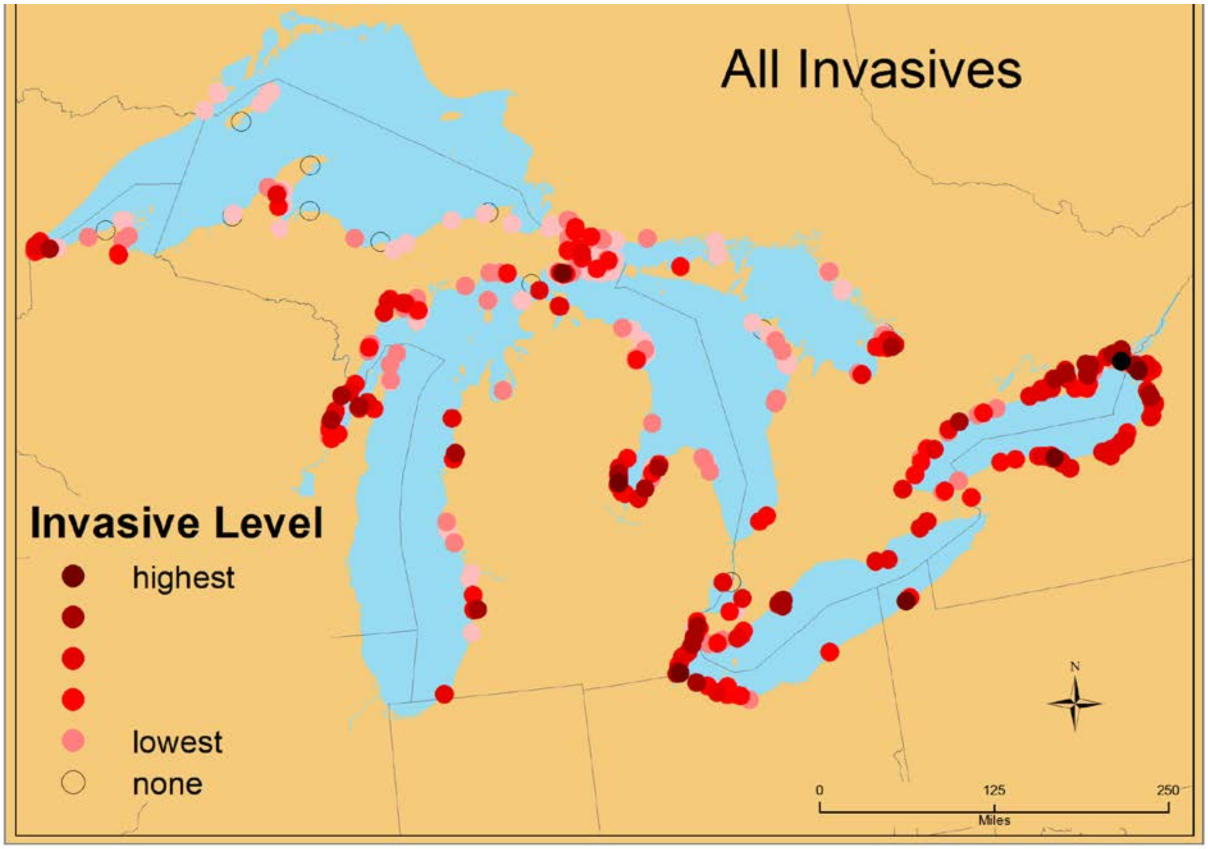

Figure 10. Level of "invadedness" of Great Lakes coastal wetlands for all non-native taxa combined across all taxonomic groups, based on data from 2011-2014.

Wetland Condition

In the fall of 2012 we began calculating metrics and IBIs for various taxa. We are evaluating coastal wetland condition using a variety of biota (wetland vegetation, aquatic macroinvertebrates, fish, birds, and amphibians).

Macrophytic vegetation (only large plants; algal species were not included) has been used for many years as an indicator of wetland condition. One very common and well-recognized indicator is the Floristic Quality Index (FQI); this evaluates the quality of a plant community using all of the plants at a site. Each species is given a Coefficient of Conservatism (C) score based on the level of disturbance that characterizes each plant species' habitat. A species found in only undisturbed, high quality sites will have a high C score (maximum 10), while a weedy species will have a low C score (minimum 0). We also give invasive and non-native species a rank of 0. These C scores have been determined for various areas of the country by plant experts; we used the published C values for the midwest. The FQI is an average of all of the C scores of the species growing at a site divided by the square root of the number of species. The CWM wetland vegetation index is based largely on C scores for wetland species.

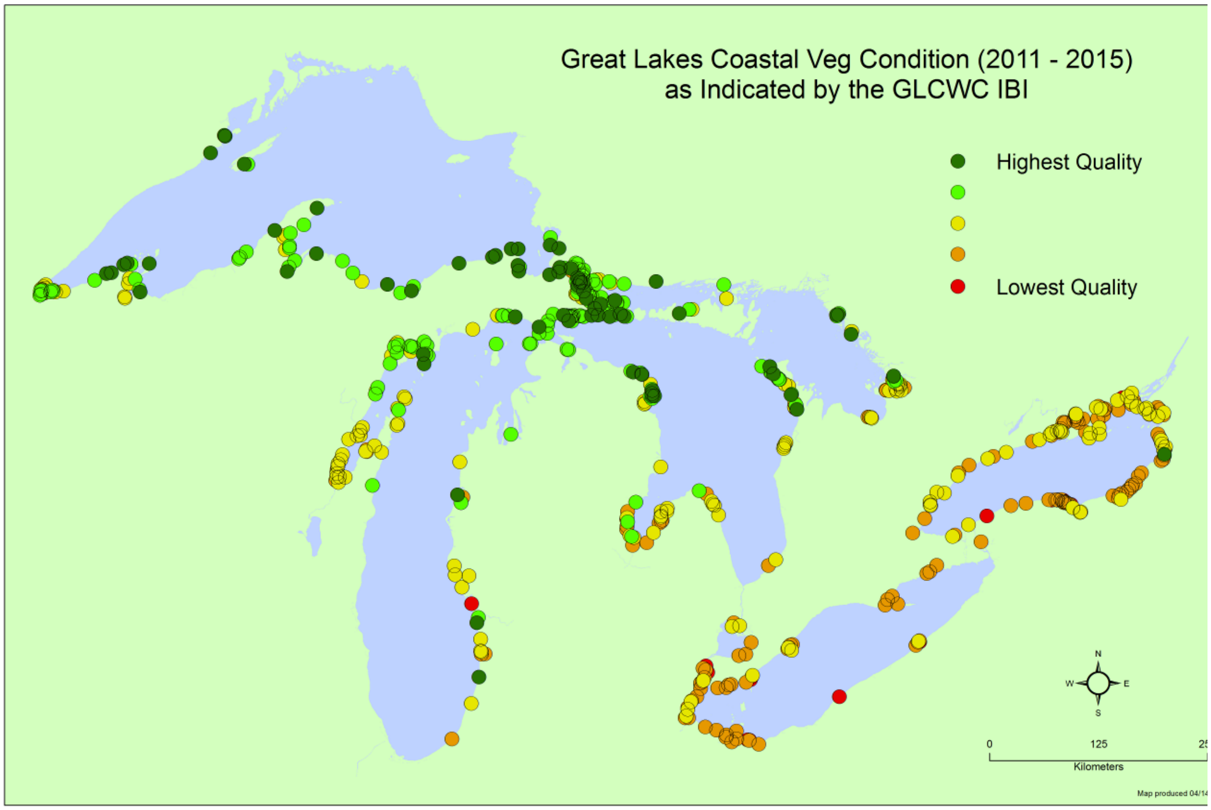

Figure 11. Condition of coastal wetland vegetation at sites across the Great Lakes. Circle color indicates vegetation community quality. The indicator is labeled “draft” while this indicator is investigated for robustness against varying water levels and latitude. Based on data from 2011 through 2015.

The map (Figure 11) shows the distribution of Great Lakes coastal wetland vegetation index scores across the basin. Note that there are long stretches of Great Lakes coastline that do not have coastal wetlands due to topography and geology. Sites with low FQI scores are concentrated in the southern Great Lakes, where there are large amounts of both agriculture and urban development, and where water levels may be more tightly regulated (e.g., Lake Ontario), while sites with high FQI scores are concentrated in the northern Great Lakes. Even in the north, an urban area like Duluth, MN may have high quality wetlands in protected sites and lower quality degraded wetlands in the lower reaches of estuaries (drowned river mouths) where there are legacy effects from the pre-Clean Water Act era, along with nutrient enrichment or heavy siltation from industrial development and/or sewage effluent. Benchmark sites in need of restoration will also have lower condition scores. Note that this IBI has been updated and adjusted since the start of the project, accounting for the shift in condition scores for a handful of sites. This adjustment was necessary to reflect changes in the taxonomic treatment of many marsh plants in the 2012 Michigan Flora and Flora of North America.

Another of the IBIs that was developed by the Great Lakes Coastal Wetlands Consortium uses the aquatic macroinvertebrates found in several of the most common vegetation types in Great Lakes coastal wetlands: sparse bulrush (*Schoenoplectus*), dense bulrush (*Schoenoplectus*), and wet meadow (multi-species) zones. We have calculated these IBIs for sites that contain these habitat zones (Figure 12). Minor adjustment of metrics is continuing, so maps are not directly comparable across reports.

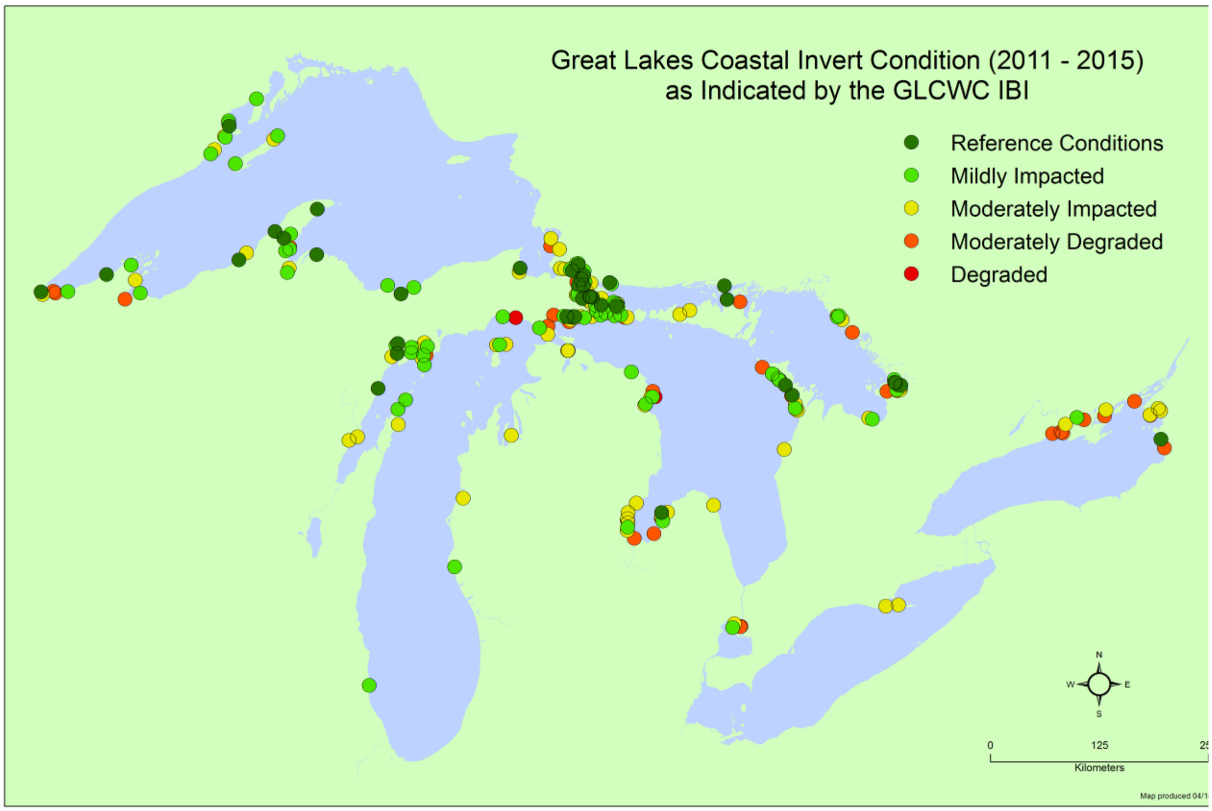

Figure 12. Condition of coastal wetland macroinvertebrate communties at sites with bulrush or wet meadow zones. The indicator is labeled "draft" while more zone IBIs are calculated. Based on data from 2011 through 2015.

The lack of sites on lakes Erie and Ontario and southern Lake Michigan is due to either a lack of wetlands (southern Lake Michigan and parts of Erie and Ontario) or because these areas do not contain any of the three specific vegetation zones that GLCWC used to develop and test the invertebrate IBI. Many areas contain dense cattail stands (e.g., southern Green Bay, much of Lake Ontario) for which we do not yet have a published macroinvertebrate IBI. We are developing IBIs for additional vegetation zones to cover these sites, but these IBIs have not yet been validated so they are not included here.

We are currently able to report draft fish IBI scores for wetland sites containing bulrush and/or cattail zones (Figure 13). These are the two zone types with GLCWC validated fish IBIs. Because of the prevalence of cattail zones in Erie and Ontario wetlands, this indicator provides more site scores than the macroinvertebrate indicator. Only a few wetlands rank as high quality with the fish IBI. We are still working to determine whether we have set the criteria for this indicator too stringently, or if fish communities really are relatively degraded in many areas.

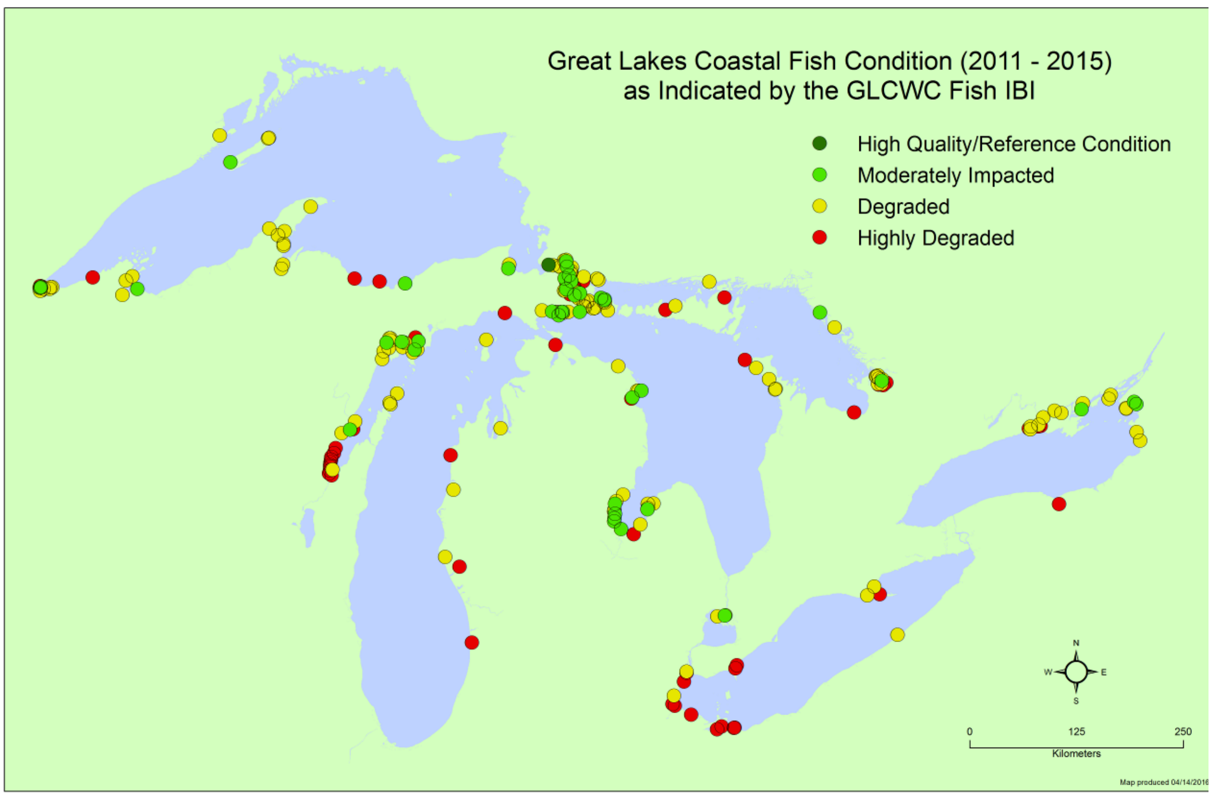

Figure 13. Condition of coastal wetland fish communties at sites with bulrush or cattail zones. The indicator is labeled "draft" while more zone IBIs are developed. Based on data from 2011 through 2015.

Fisheries researchers have been in the process of updating and expanding the fish-based IBIs of Uzarski *et al*. (2005). Fish data collected from 2011-2013 at 254 wetlands were used to develop the updated IBI. Metrics were evaluated against numerous indices of anthropogenic disturbance derived from measurements of water quality and surrounding land cover. Disturbance indices included individual land cover and water quality variables, principal components combining land cover and water quality variables, a previously published landscape-based index (SumRel; Danz *et al*. 2005), and a rank-based index combining land cover and water quality variables (RankSum; Uzarski *et al*. 2005). Multiple disturbance indices were used to ensure that IBI metrics captured various dimensions of human disturbances.

We divided fish, water quality, and land cover data into separate "development" and "testing" sets for metric identification/calibration and final IBI testing, respectively. Metric identification and IBI development generally followed previously established methods (e.g., Karr *et al*. 1981, USEPA 2002, Lyons 2012) in which 1) a large set of candidate metrics was calculated; 2) metrics were tested for response to anthropogenic disturbance or habitat quality; 3) metrics were screened for responses to anomalous catches of certain taxa, for adequate range of responses, and for highly redundant metrics; 4) scoring schemes were devised for each of the final metrics; 5) the final set of metrics was optimized to improve the fit of the IBI to anthropogenic disturbance gradients; and 6) the final IBI was validated against an independent data set.

Final IBIs were composed of 10-15 metrics for each of four vegetation types (bulrush [*Schoenoplectus* spp.], cattail [*Typha* spp.], water lily [*Brassenia, Nuphar, Nymphaea* spp.], and submersed aquatic vegetation [SAV, primarily *Myriophyllum* or *Ceratophyllum* spp.]). Scores of all IBIs correlated well with values of anthropogenic disturbance indices using the development and testing data sets. Correlations of IBIs to disturbance scores were also consistent among each of the three years. The updated IBI was then applied to 2014 and 2015 data and relationships between disturbance scores and IBI scores remained consistent.

Avian and amphibian responses to landscape stressors can be used to inform land managers about the health of coastal wetlands and the landscape stressors that affect these systems (Howe *et al*. 2007). A bird index based on the Index of Ecological Condition (IEC) method developed by Dr. Robert Howe was calculated for Great Lakes coastal wetlands (Figure 14). The IEC is a biotic indicator of ecological health first described by Howe *et al*. (2007a,b) and modified by Gnass-Giese *et al*. (2014). Calculation of an IEC involves two steps: 1) modeling responses of species to a measured reference or stressor gradient (typically completed by prior research), and 2) calculating IEC values for new sites based occurrences (e.g., presence/absence, abundance, frequency) of multiple species or taxonomic groups at the site. The method applies an iterative maximum likelihood approach for calculating both species-response functions and IEC values. Functions for calculating the biotic responses to environmental stressors (BR models) are useful as stand-alone applications of environmental gradient analysis. This indicator should be considered a draft because we are still exploring its implications and are still analyzing whether adjustments sufficiently account for differences due to latitude across the entire Great Lakes basin.

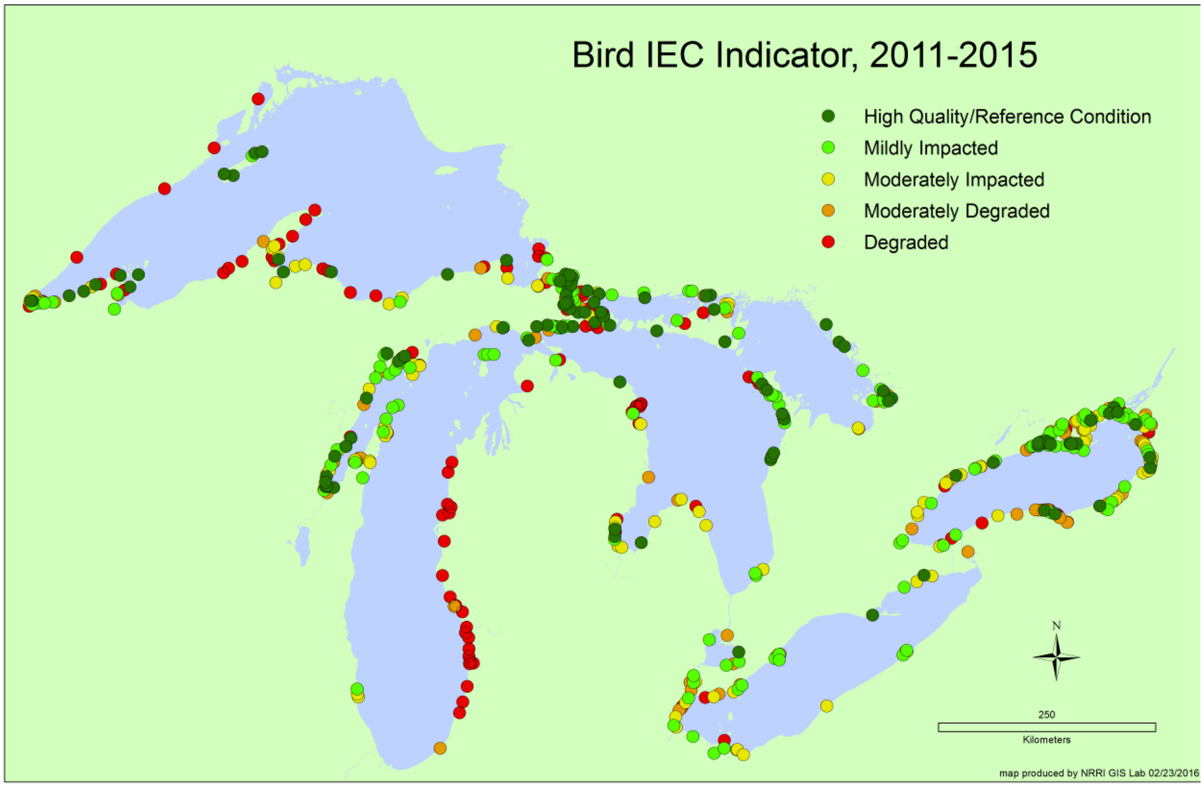

Figure 14. Condition of coastal wetland bird communties. This indicator is based on the IEC method. Based on data from 2011 through 2015.

As noted above, there is little diversity in amphibians across Great Lakes wetlands. However, the IEC method has allowed development of a trial calling anuran indicator (Figure 15). The indicator is shown on separate scales for the northern and southern parts of the Great Lakes basin because of the differences in amounts of agriculture and development between these two areas. This can be seen in particular along the eastern coast of Lake Michigan on either side of the north/south split in the basin. Some adjustment may be necessary to avoid discrepancies in treatment of sites that are close to the boundary line. However, benchmark sites also exhibit low calling frog IBI scores even in locations such as Duluth, on Lake Superior.

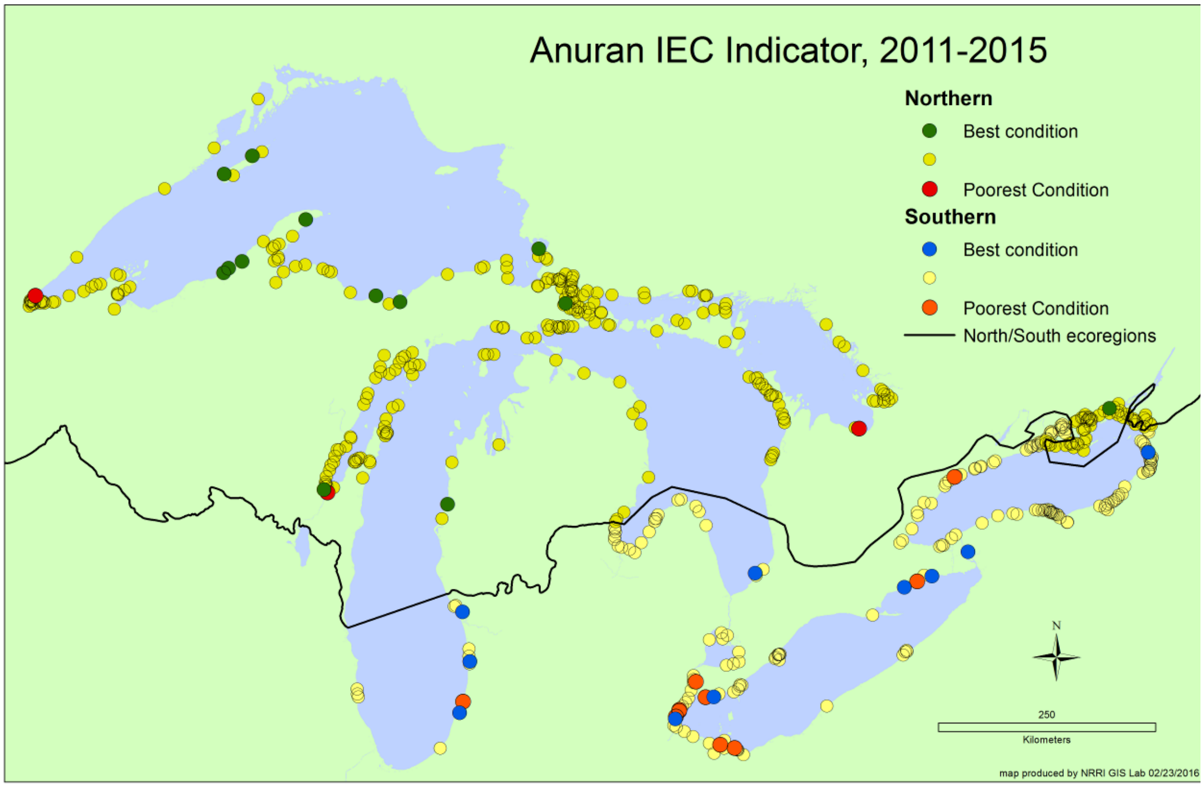

Figure 15. Condition of coastal wetland calling amphibian communties. This indicator is based on the IEC method, and it works best when shown separately for the northern and southern areas of the Great Lakes because of the differences in the amount of agriculture and developed land between these two areas (see text for details). Based on data from 2011 through 2015.

Finally, we have developed a draft disturbance gradient (SumRank) indicator. This indicator is based on landscape stressor data, local stressor data seen at the site itself, and water quality data collected from each aquatic macrophyte plant morphotype (Figure 16). This example is based on data from 2014. Wetlands can have different scores for each plant morphotype within them because of the difference in water chemistry among different plant zones (inset a). In addition, the indicator may change over time, as indicated in Figure 16 inset b.

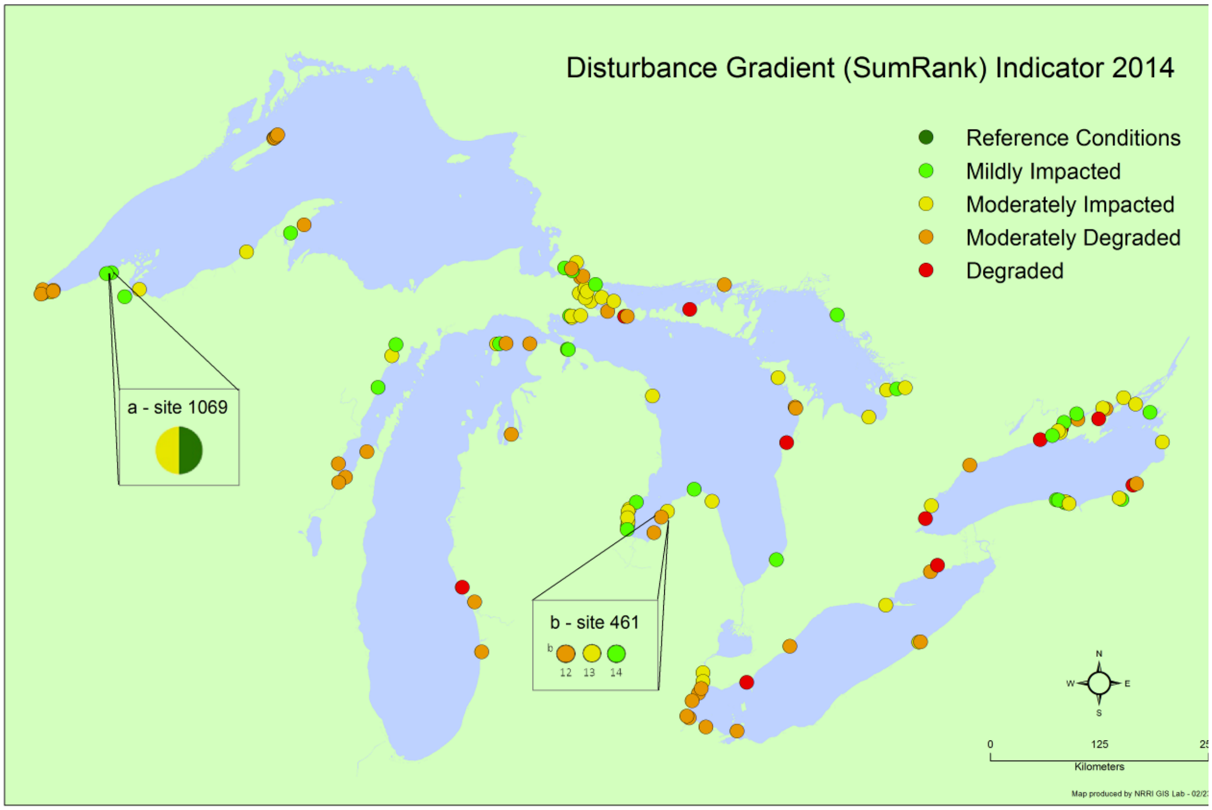

Figure 16. Draft disturbance gradient (SumRank) indicator. This indicator is based on landscape stressor data, site-based stressor data, and site water quality data. This example is based on data from 2014. Wetlands can have different scores for each plant morphotype within them (a), and the indicator may change over time (b).

PUBLIC ACCESS WEBSITE

The Coastal Wetlands Monitoring Program (CWMP) public website provides efficient access to program information and summary results for coastal managers, agency personnel, and the interested public (Figure 17). The website was developed by LimnoTech and is hosted at Central Michigan University.

Figure 17. Front page of the Great Lakes Coastal Wetland Monitoring public website, www.greatlakeswetlands.org.

The public website provides a suite of interrelated webpages and associated tools that allow varying levels of access to results generated by the project, depending on the user's data needs and affiliation. Webpages available on the site allow potential users to request an account and for site administrators to approve and manage access levels for individual accounts. Specific levels of access for the website are as follows:

- **Public** – this level of access does not require a user account and includes access to a basic version of the wetland mapping tool, as well as links to project documents and contact information;
- **Level 1** – provides access to index of biological integrity (IBI) scores by wetland site via the coastal wetland mapping tool;
- **Level 2** - access to IBI scores and full species lists by wetland site via mapping tool;
- **Level 3** - access to export tools for raw datasets (+ Level 2 capabilities);
- **Level 4** - access to data entry/editing tools (+ Level 3 capabilities); and
- **Admin** - access to all information and data included on the website plus administrative tools. A small team of project principal investigators have been given "Admin" access and will handle approval of account requests and assignment of an access level (1-4).

The following sub-sections briefly describe the general site pages that are made available to all users ("Public" level) and the coastal wetland mapping tool features available to "Level 1" and "Level 2" users. Additional pages and tools available to "Level 3", "Level 4", and "Admin" users for exporting raw monitoring data, entering and editing raw data, and performing administrative tasks are not documented in detail in this report.

General Site Pages

The public website provides open "Public" access (i.e., without requiring a user account) to the following site content:

- Mapping tool – basic version (http://www.greatlakeswetlands.org/Map);
- CWMP documents (Figure 18; http://www.greatlakeswetlands.org/Documents);
- Program contact information (http://www.greatlakeswetlands.org/Contact);
- Program collaborators (http://www.greatlakeswetlands.org/Collaborators); and
- User account request form (http://www.greatlakeswetlands.org/Account/Request).

The "Documents" page provides links to PDF and Microsoft Word documents for program reports, the current version of the quality assurance project plan (QAPP), quality assurance forms, standard operating procedure (SOP) documents, and presentation templates. The "Contact" page provides contact information for Dr. Uzarski, Dr. Brady, and Dr. Cooper.

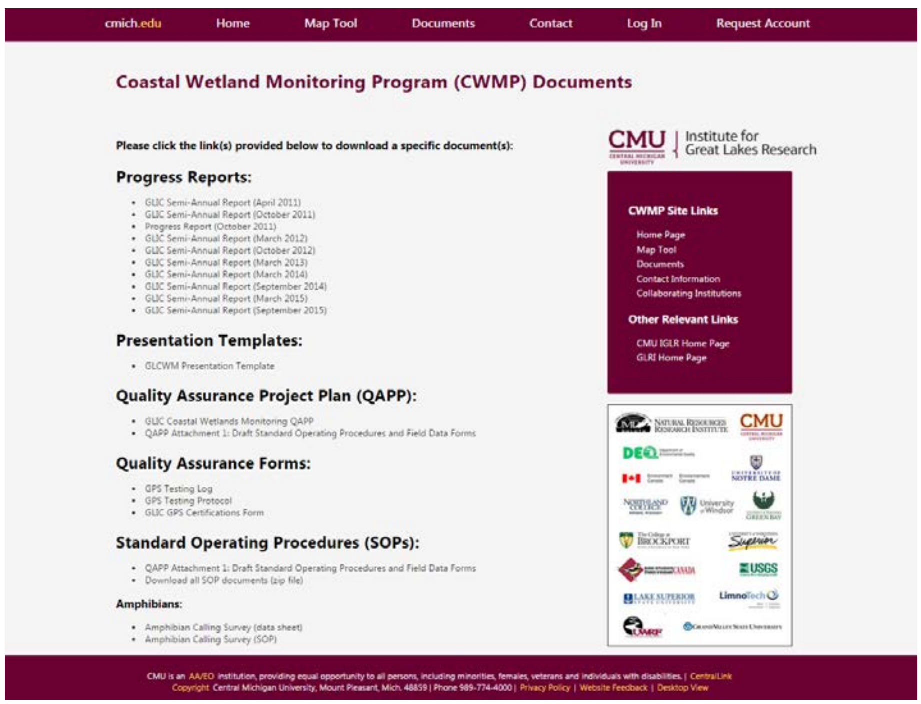

Figure 18. The Documents Download webpage.

Coastal Wetland Mapping Tool

The enhanced public website provides a new and updated version of the coastal wetland mapping tool described in previous reports (http://www.greatlakeswetlands.org/Map). The basic version of the mapping tool, which is available at the "Public" access level, provides the following features and capabilities (Figure 19):

- Map navigation tools (panning, general zooming, zooming to a specific site etc.);
- Basemap layer control (selection of aerial vs. "ocean" basemaps);
- Display of centroids and polygons representing coastal wetlands that have been monitored thus far under the CWMP;
- Capability to style/symbolize wetland centroids based on: 1) geomorphic type (default view; Figure 19), or 2) year sampled (Figure 20); and
- Reporting of basic site attributes (site name, geomorphic type, latitude, longitude, and sampling years).

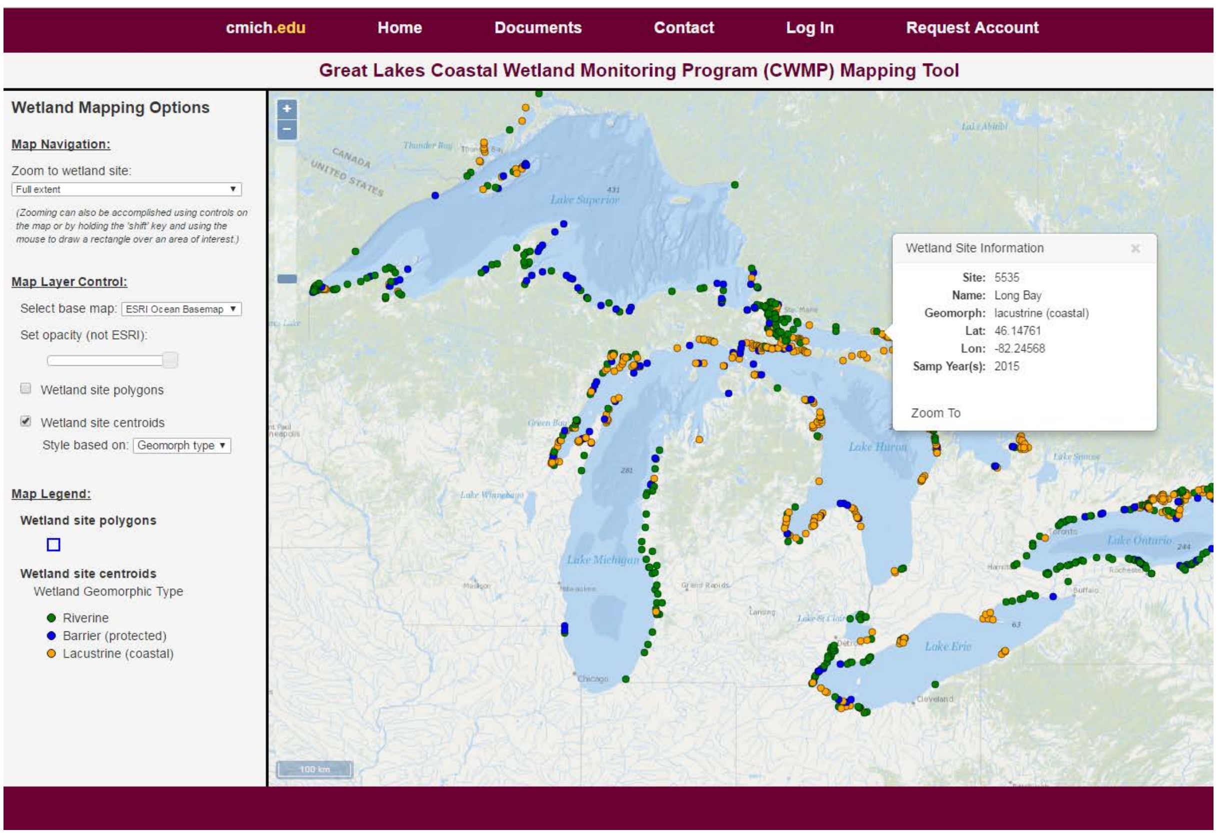

Figure 19. Mapping Tool webpage. Sites are color-coded by wetland type (protected, riverine, or open coastal). Only sites that have been sampled are shown.

In addition to the features made available at the "Public" access level, users with "Level 1" access to the website can currently obtain information regarding IBI scores for vegetation, invertebrates, and fish.

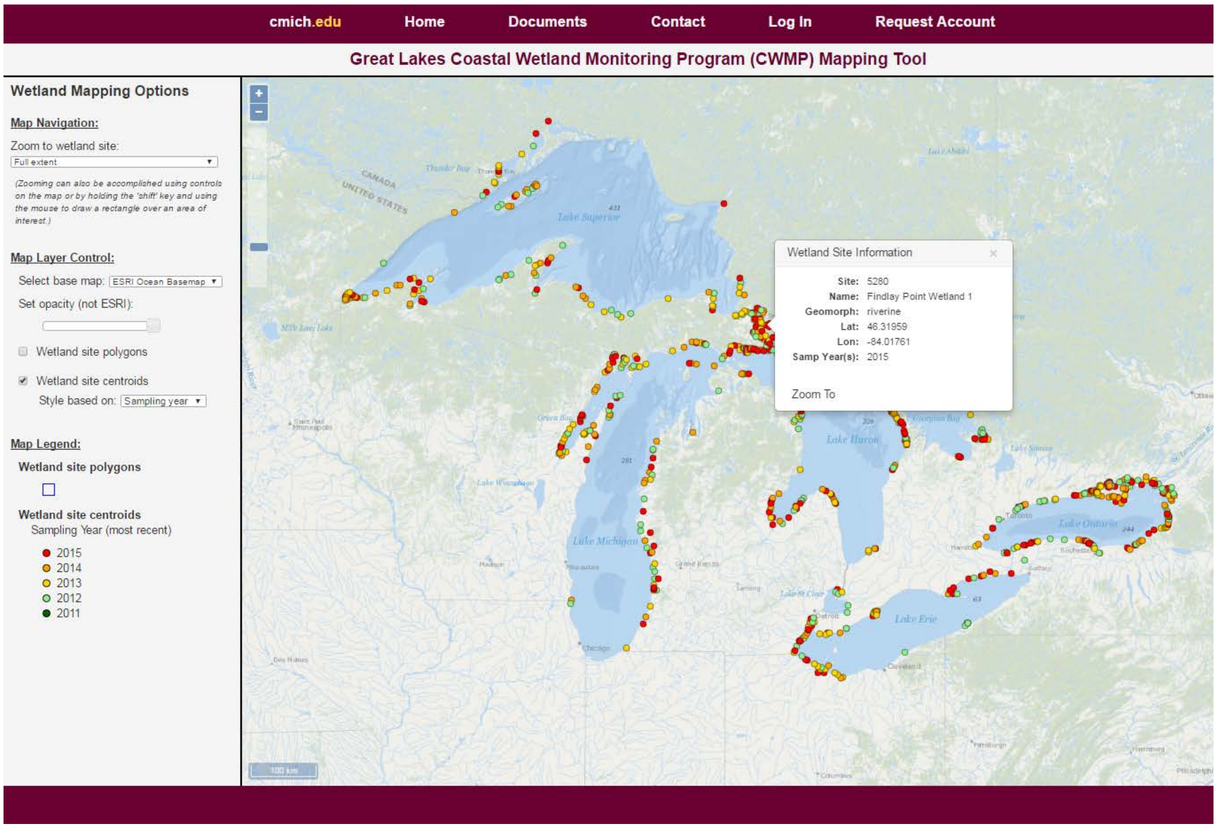

Figure 20. Mapping Tool webpage. Sites are color-coded by year sampled.

Wetland centroids can be symbolized based on IBI scores for a specific biological community, as well as based on geomorphic type and year sampled. For example, vegetation IBI scores calculated for individual sites can be displayed by selecting the "Vegetation IBI" option available in the "Style based on:" pull-down menu (Figure 21). In addition, the actual IBI scores can be viewed by clicking on an individual wetland centroid.

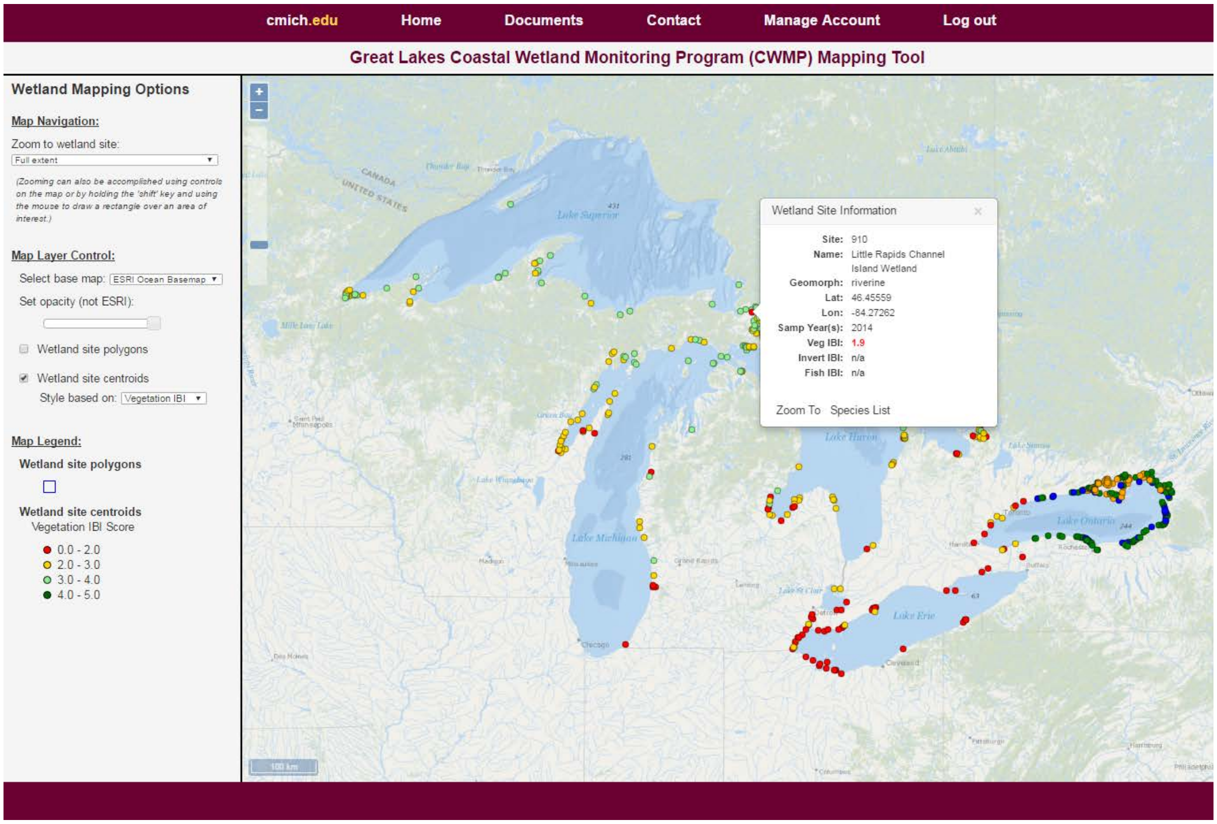

Figure 21. Coastal Wetland Mapping Tool with IBI scores displayed.

Users with “Level 2” access to the website are provided with the same visualization options described above for the “Public” and “Level 1” access levels, but also have the capability of viewing a complete listing of species observed at individual wetland sites. Species lists can be generated by clicking on the “Species List” link provided at the bottom of the “pop-up” summary of site attributes (Figure 22), and the information can then be viewed and copied and pasted to another document, if desired.

Website Access

The CWMP site administrators approve accounts with appropriate levels of access depending on the requestor’s affiliation and intended use of the data. CWMP principal investigators and team members have user accounts that provide access to raw data management tools.

TEAM SUMMARIES

WESTERN REGIONAL TEAM: Jerry Niemi (Birds and Amphibians), Valerie Brady and Lucinda Johnson (Fish and Macroinvertebrates), Nicholas Danz (Vegetation), and Rich Axler (Water Quality)

Whole Basin Bird and Amphibian Summary Report – 2011-2015

General. The bird and amphibian (specifically frogs or anurans) teams have sampled a total of 902 wetland sites from 2011 to 2015 ranging from 149 in 2011 to 194 in 2014 (Table 13). Each wetland site has a variable number of points in which species and individuals are recorded based on the size of the wetland, but on average an impressive 26 bird species and 108 individuals were detected per wetland site.

Table 13. Total number of sites sampled by bird and amphibian teams across the Great Lakes (2011-2015). For each year, mean species richness per site (Mean SR), mean total bird detections per site (Mean Detections), and mean focal species detections per site (Mean Focal Species) are listed.

Year	*Sites Sampled*	*Mean SR*	*Mean Detections*	*Mean Focal Species*
2011	149	28.32	96.35	1.32
2012	185	23.97	73.25	0.95
2013	183	25.31	87.65	1.21
2014	194	25.46	170.10	1.98
2015	191	27.73	113.90	2.05
Grand Total	**902**	**26.16**	**108.25**	**1.50**

Birds. The breeding bird protocol also includes audio playback for species of particular interest, referred to as focal species, to aid in their detection. These species include the Pied-billed Grebe, American Bittern, Least Bittern, Virginia Rail, American Coot, and Common Moorhen. These species either have national, state, or provincial designated status; are declining; and/or have high affinities to Great Lakes coastal wetland habitats. A total of 1,358 detections have been recorded for these species from 2011-2015 among the 902 wetlands sampled (Table 14). The number of detections ranged from 175 in 2012 to 386 in 2015. An average of 1.5 focal species were detected per wetland site over the course of the five years among the 902 sites (Table 14). Among these species, the Pied-billed Grebe was the most frequently detected among the 6 focal species with 413 detections.

Table 14. Total bird focal species detections by year for all five years of sampling (2011-2015).

	Year					
Focal Species	*2011*	*2012*	*2013*	*2014*	*2015*	*Total*
Pied-billed Grebe	58	49	67	95	144	413
American Bittern	51	34	53	77	67	282
Least Bittern	27	20	15	67	40	169
Virginia Rail	43	57	42	66	73	281
American Coot	3	1	6	2	14	26
Common Moorhen	14	14	36	75	48	187
Grand Total	**196**	**175**	**219**	**382**	**386**	**1358**

Frogs. Of the total of 902 wetlands, frogs have been sampled in 866 wetlands; varying from 147 in 2011 to 186 in 2013 (Table 15). Some sites that are reasonable to access during daylight are too difficult or dangerous to access at night or inclement weather may have prevented sampling. In the latter case it may have been logistically inefficient to stay or return to sample the site given the restricted sampling periods in spring and summer.

All 13 of the frog species that should reasonably be expected to occur in Great Lakes coastal wetlands have been recorded during the counts of 866 wetlands (Table 16). Four of these species, however, are very uncommon in Great Lakes coastal wetlands. These include 1) the pickerel frog (*Lithobates* palustris) with one individual detected at only one site, 2) Blanchard's cricket frog (*Acris blanchardii*) with 3 individuals detected at 3 sites and 4 detections of choruses at 4 locations, 3) Cope's gray tree frog (*Hyla chrysoscelis*) with 7 detections, and 4) Fowler's toad (*Bufo fowleri*) with 10 detections. The two most common frog species detected were the green frog (*Lithobates clamitans*) with 7,820 total detections and the spring peeper (*Pseudacris crucifer*) with 8,367 detections. One species to keep a careful watch over in the Great Lakes is the American bullfrog (*Lithobates catesbeianus*). Even though the species is native to the eastern US and historically found in the southern regions of the Great Lakes, it has been introduced in many areas outside of its range. Our data show an increase in the population over time (Table 16). The species is used by many wildlife species and humans for food, but it has also been suggested to harbor the chytrid fungus (*Batrachochytrium dendrobatidis*) which has been associated with amphibian mortality in many localities.

Table 15. Number of sites sampled for frogs for all five years of sampling (2011-2015).

year	*Sites Sampled*
2011	147
2012	174
2013	186
2014	182
2015	177

Table 16. Total number of frog observations by calling code and year for all five years of sampling (2011-2015). Calling codes represent the following: 1 = individuals can be accurately counted, 2= individuals can be reliably estimated, and 3 = overlapping, not reliably estimated (i.e., full chorus).

species	*year*	*code 1*	*code 2*	*code 3*	*# individuals*	*# choruses*	*Total Detections*
American Toad	2011	252	208	69	460	69	529
	2012	143	134	47	277	47	324
	2013	262	293	46	555	46	601
	2014	210	130	46	340	46	386
	2015	187	230	73	417	73	490
Blanchard's Cricket Frog	2011	1	0	0	1	0	1
	2012	2	0	0	2	0	2
	2013	0	0	0	0	0	0
	2014	0	0	4	0	4	4
	2015	0	0	0	0	0	0
American Bullfrog	2011	156	44	1	200	1	201
	2012	129	111	51	240	51	291
	2013	134	90	9	224	9	233
	2014	156	118	3	274	3	277
	2015	276	188	4	464	4	468

Table 16. (cont.)

species	*year*	*code 1*	*code 2*	*code 3*	*# individuals*	*# choruses*	*Total Detections*
Chorus Frog (Western/Boreal)	2011	100	109	55	209	55	264
	2012	46	52	21	98	21	119
	2013	69	44	29	113	29	142
	2014	100	72	52	172	52	224
	2015	151	112	54	263	54	317
Cope's Gray Treefrog	2011	0	4	0	4	0	4
	2012	1	0	0	1	0	1
	2013	1	0	0	1	0	1
	2014	0	0	0	0	0	0
	2015	0	0	1	0	1	1
Fowler's Toad	2011	0	0	0	0	0	0
	2012	5	4	0	9	0	9
	2013	0	0	0	0	0	0
	2014	0	0	0	0	0	0
	2015	1	0	0	1	0	1
Gray Treefrog	2011	433	250	127	683	127	810
	2012	171	218	119	389	119	508
	2013	357	258	95	615	95	710
	2014	348	357	181	705	181	886
	2015	315	521	154	836	154	990
Green Frog	2011	792	451	36	1243	36	1279
	2012	594	458	89	1052	89	1141
	2013	682	464	38	1146	38	1184
	2014	878	620	51	1498	51	1549
	2015	824	931	46	1755	46	1801
Mink Frog	2011	5	0	0	5	0	5
	2012	9	6	0	15	0	15
	2013	0	0	0	0	0	0
	2014	12	0	0	12	0	12
	2015	18	2	8	20	8	28

Table 16. (cont.)

species	*year*	*code 1*	*code 2*	*code 3*	*# individuals*	*# choruses*	*Total Detections*
Northern Leopard Frog	2011	207	156	20	363	20	383
	2012	148	164	6	312	6	318
	2013	230	140	22	370	22	392
	2014	220	224	42	444	42	486
	2015	346	388	54	734	54	788
Pickerel Frog	2011	0	0	0	0	0	0
	2012	0	0	0	0	0	0
	2013	0	0	0	0	0	0
	2014	1	0	0	1	0	1
	2015	0	0	0	0	0	0
Spring Peeper	2011	543	810	490	1353	490	1843
	2012	158	515	463	673	463	1136
	2013	592	796	433	1388	433	1821
	2014	356	927	532	1283	532	1815
	2015	411	829	512	1240	512	1752
Wood Frog	2011	59	46	5	105	5	110
	2012	33	19	5	52	5	57
	2013	157	107	6	264	6	270
	2014	101	108	20	209	20	229
	2015	104	85	13	189	13	202

Bird species. A total of 219 bird species have been recorded during the breeding bird counts in May to July (Table 17). Several species are late migrants that nest farther north in Canada. Examples include Tundra Swan, Long-tailed Duck, Greater and Lesser Scaup, many species of shorebirds (e.g., Greater and Lesser Yellowlegs, Sanderling, Pectoral Sandpiper, Whimbrel, Semipalmated Sandpiper, Black-bellied Plover, Semipalmated Plover, and Dunlin), Bonaparte's Gull, Gray-cheeked Thrush, Blackpoll Warbler, American Tree Sparrow, White-crowned Sparrow, and Pine Grosbeak. Note also that many of these species may not be dependent on Great Lakes wetlands for nesting but may use the wetlands or surrounding areas for foraging or cover during migration. These areas would include open water within the wetland (e.g., waterfowl, gulls, and terns), grass-sedge, shrubs, or forested areas within or adjacent to the wetland (e.g., raptors, woodpeckers, or a variety of songbirds), and airspace above the wetlands abundantly used by flycatchers and swallows. Virtually all of these species use these wetland or their edges for some part of their life cycle.

Among the 219 species include:

1) 2 species of grebes – the Pied- billed Grebe and Red-necked Grebe;
2) 7 species of herons, egrets, and bitterns including 198 detections of Least Bittern;
3) 24 species of waterfowl including swans, geese, ducks, and mergansers;
4) 17 raptor species including Bald Eagle, Osprey, hawks, falcons, and owls;
5) 6 species of rail including 2 observations of the extremely rare King Rail;
6) 18 species of shorebirds including two game species American Woodcock and Wilson's Snipe;
7) 8 gull species and tern species, including 382 observations of Black-Tern;
8) 10 species of flycatchers with over 1200 observations of Alder and Willow Flycatchers;
9) 6 species of swallows, including Purple Martin– all the species that occur in eastern North America and with over 14,000 observations of individuals foraging over wetlands;
10) 7 species of thrushes;
11) 25 species of warblers including Golden-winged, Cape May, Bay-breasted, and Canada Warbler;
12) 13 sparrow species including 3 Henslow Sparrow detections; and
13) 10 species of blackbirds.

The most abundant bird species recorded include some impressive numbers: 28,080 Red-winged Blackbirds, 13,442 Ring-billed Gulls, 9740 Common Grackle, 9711 Canada Geese, 9077 Double-crested Cormorants, 6266 Tree Swallows, 6033 White Pelicans, 5651 Herring Gulls, 5147 Common Yellowthroat, 4849 Yellow Warblers, 4796 Swamp Sparrows, 4461 American Robins, 4446 Barn Swallows, 4445 Song Sparrows, 3547 Mallards, 2,662 Marsh Wrens, 1762 American Goldfinch, 1164 Northern Cardinal, 1121 Bank Swallows, 993 Caspian Terns, 905 Common Terns, 885 Cliff Swallows, 758 Sandhill Cranes, 588 Eastern Kingbirds, 553 Red-breasted Mergansers, 476 Bald Eagles, 396 Belted Kingfishers, 364 Virginia Rails, 283 Common Raven, 254 Forster's Terns, 207 Chimney Swifts, and 156 Red-bellied Woodpeckers. Collectively these numbers and the systematic counts represent a solid baseline on wetland use by birds from 2011-2015 in the Great Lakes ecosystem.

Relative to other taxa, birds have not been as heavily influenced by exotic species; however, several species are found in the Great Lakes ecosystem. These species are exotics that have been introduced from other continents (number of observations in parentheses): European Starling (6405), Mute Swan (1393), House Sparrow (444), Rock Dove (180), Ring-necked Pheasant (24) , and Common Peafowl (2). Of these, the greatest concerns have focused on

European Starlings and their detrimental effects on cavity-nesting species such as European Bluebirds. Mute Swans are of concern because of their overgrazing on aquatic vegetation and their aggressive behavior can displace native waterfowl. Several other native species, especially Ring-billed Gulls and Canada Geese, have also become a concern in many portions of the Great Lakes because of their relatively recent expansions of both distribution and populations. Many serious problems have emerged from their exploding populations that range from displacing native species to eutrophication of water bodies and disease transmission from their fecal material.

Table 17. List of bird species observed for all five years of sampling (2011-2015).

Taxa.code	Taxa	Number of individuals
2	Common Loon	214
3	Pied-billed Grebe	559
4	Red-necked Grebe	3
6	American White Pelican	6033
7	Double-crested Cormorant	9077
8	American Bittern	352
9	Least Bittern	198
10	Great Blue Heron	1264
11	Great Egret	1503
15	Black-crowned Night Heron	204
17	Tundra Swan	2
19	Canada Goose	9711
20	Wood Duck	1034
21	Green-winged Teal	3
22	American Black Duck	36
23	Mallard	3547
24	Northern Pintail	2
25	Blue-winged Teal	93
26	Northern Shoveler	28
27	Gadwall	41
28	American Wigeon	25
29	Canvasback	14
30	Redhead	20
31	Ring-necked Duck	4
32	Greater Scaup	14
33	Lesser Scaup	17
34	Common Goldeneye	74

Table 17. (cont.)

Taxa.code	Taxa	Number of individuals
36	Hooded Merganser	37
37	Common Merganser	361
38	Red-breasted Merganser	553
39	Ruddy Duck	7
40	Turkey Vulture	354
41	Osprey	300
42	Bald Eagle	476
43	Northern Harrier	89
44	Sharp-shinned Hawk	5
45	Cooper's Hawk	19
46	Northern Goshawk	2
47	Red-shouldered Hawk	3
48	Broad-winged Hawk	6
50	Red-tailed Hawk	55
51	American Kestrel	11
52	Merlin	37
53	Peregrine Falcon	2
56	Ring-necked Pheasant	24
58	Ruffed Grouse	46
61	Wild Turkey	18
63	Yellow Rail	2
64	Virginia Rail	364
65	Sora	203
66	American Coot	41
67	Sandhill Crane	758
68	Killdeer	716
70	Greater Yellowlegs	3
71	Lesser Yellowlegs	3
72	Solitary Sandpiper	3
73	Spotted Sandpiper	153
74	Upland Sandpiper	2
75	Marbled Godwit	2
76	Sanderling	7
77	Pectoral Sandpiper	5
79	Wilson's Snipe	258
80	American Woodcock	34
81	Wilson's Phalarope	3

Table 17. (cont.)

Taxa.code	Taxa	Number of individuals
83	Ring-billed Gull	13442
84	Herring Gull	5651
85	Caspian Tern	993
86	Common Tern	905
87	Forster's Tern	254
88	Black Tern	382
89	Rock Dove	180
91	Mourning Dove	2107
92	Black-billed Cuckoo	37
93	Yellow-billed Cuckoo	16
95	Great Horned Owl	7
97	Barred Owl	1
99	Long-eared Owl	2
102	Northern Saw-whet Owl	1
103	Common Nighthawk	101
104	Whip-poor-will	15
105	Chimney Swift	207
106	Ruby-throated Hummingbird	65
107	Belted Kingfisher	396
108	Red-headed Woodpecker	7
109	Red-bellied Woodpecker	156
110	Yellow-bellied Sapsucker	70
111	Downy Woodpecker	262
112	Hairy Woodpecker	97
114	Black-backed Woodpecker	1
115	Northern Flicker	724
116	Pileated Woodpecker	112
117	Olive-sided Flycatcher	3
118	Eastern Wood-Pewee	166
119	Yellow-bellied Flycatcher	6
120	Acadian Flycatcher	1
121	Alder Flycatcher	799
122	Willow Flycatcher	499
123	Least Flycatcher	85
124	Eastern Phoebe	142
125	Great Crested Flycatcher	300
127	Eastern Kingbird	588

Table 17. (Cont.)

Taxa.code	Taxa	Number of individuals
128	Horned Lark	2
129	Purple Martin	1275
130	Tree Swallow	6266
131	N. Rough-winged Swallow	595
132	Bank Swallow	1121
133	Cliff Swallow	885
134	Barn Swallow	4446
135	Gray Jay	9
136	Blue Jay	1152
138	American Crow	2599
139	Common Raven	283
140	Black-capped Chickadee	779
141	Boreal Chickadee	2
142	Tufted Titmouse	8
143	Red-breasted Nuthatch	133
144	White-breasted Nuthatch	90
145	Brown Creeper	8
146	House Wren	339
147	Winter Wren	104
148	Sedge Wren	350
149	Marsh Wren	2662
150	Golden-crowned Kinglet	27
151	Ruby-crowned Kinglet	9
152	Blue-gray Gnatcatcher	51
153	Eastern Bluebird	27
154	Veery	675
155	Gray-cheeked Thrush	1
156	Swainson's Thrush	33
157	Hermit Thrush	181
158	Wood Thrush	102
159	American Robin	4461
160	Gray Catbird	1155
161	Northern Mockingbird	4
162	Brown Thrasher	88
164	Cedar Waxwing	2575
167	European Starling	6405
169	Blue-headed Vireo	22

Table 17. (cont.)

Taxa.code	Taxa	Number of individuals
170	Yellow-throated Vireo	13
171	Warbling Vireo	916
173	Red-eyed Vireo	1557
174	Blue-winged Warbler	17
175	Golden-winged Warbler	8
176	Tennessee Warbler	5
178	Nashville Warbler	394
179	Northern Parula	75
180	Yellow Warbler	4849
181	Chestnut-sided Warbler	189
182	Magnolia Warbler	74
183	Cape May Warbler	7
184	Black-throated Blue Warbler	1
185	Myrtle Warbler	327
186	Black-throated Green Warbler	330
187	Blackburnian Warbler	42
188	Pine Warbler	86
190	Bay-breasted Warbler	2
191	Blackpoll Warbler	8
193	Black-and-white Warbler	254
194	American Redstart	1279
196	Ovenbird	447
197	Northern Waterthrush	31
201	Mourning Warbler	72
202	Common Yellowthroat	5147
203	Hooded Warbler	1
204	Wilson's Warbler	16
205	Canada Warbler	27
208	Scarlet Tanager	18
209	Northern Cardinal	1164
210	Rose-breasted Grosbeak	157
212	Indigo Bunting	187
214	Eastern Towhee	38
215	American Tree Sparrow	5
216	Chipping Sparrow	354
217	Clay-colored Sparrow	21
218	Field Sparrow	48

Table 17. (cont.)

Taxa.code	Taxa	Number of individuals
219	Vesper Sparrow	1
221	Savannah Sparrow	129
224	Henslow's Sparrow	3
228	Song Sparrow	4445
229	Lincoln's Sparrow	7
230	Swamp Sparrow	4796
231	White-throated Sparrow	715
232	White-crowned Sparrow	1
234	Dark-eyed Junco	3
238	Bobolink	66
239	Red-winged Blackbird	28080
240	Eastern Meadowlark	53
242	Yellow-headed Blackbird	84
243	Rusty Blackbird	2
244	Brewer's Blackbird	3
245	Common Grackle	9740
246	Brown-headed Cowbird	384
247	Orchard Oriole	19
248	Baltimore Oriole	703
249	Pine Grosbeak	1
250	Purple Finch	19
251	House Finch	148
256	Pine Siskin	3
257	American Goldfinch	1762
258	Evening Grosbeak	2
259	House Sparrow	444
283	Trumpeter Swan	115
301	Common Moorhen	254
302	Green Heron	195
303	King Rail	2
304	Common Moorhen/American Coot	3
305	Mute Swan	1393
307	Carolina Wren	25
308	Long-tailed Duck	7
310	Bonaparte's Gull	39
311	Dunlin	169
312	Semipalmated Plover	9

Table 17. (cont.)

Taxa.code	Taxa	Number of individuals
313	Black-bellied Plover	91
316	Whimbrel	59
317	Semipalmated Sandpiper	82
318	Cattle Egret	3
319	Piping Plover	1
320	Common Peafowl	2
321	Great Black-backed Gull	1

Western Basin Fish and Macroinvertebrate Summary Report – 2011-2015

From the 2011 through 2015 field seasons the NRRI field team has sampled fish from 97 distinct wetlands in Wisconsin (n= 54), Michigan (n= 34), Minnesota (n= 6), and Ontario (n= 3). Benchmark sites 1077 and 1697 were sampled for fish three times, and sites 1096 and 1039 were sampled twice between 2011 and 2015. Over five field seasons the NRRI team collected 189,000 individual fish represented by 75 species. By far, the most dominant native fish in the Great Lakes coastal wetlands we sampled were Yellow Perch (*Perca flavescens*), representing 50% of our total fish abundance. White Sucker (*Catostomus commersonii*), Brown Bullhead (*Ameiurus nebulosus*), Bluegill/Pumpkinseed (*Lepomis spp.*), Black Crappie (*Pomoxis nigromaculatus*), and Golden Shiner (*Notemigonus crysoleucas*) were also relatively abundant, as each comprised between 5-8% of our total catch.

Non-native fish species were detected in many wetlands. About 11,300 invasive fish (equal to 6% of our total fish catch) of 9 species were captured in wetlands between 2011 and 2015. Common Carp (*Cyprinus carpio*), particularly young-of-the-year, comprised 87% of our total invasive fish catch. Round Goby (*Neogobius melanostomus*) were also frequently captured and abundant, and composed 9% of the invasive fish catch. The remaining 4% of captured invasive fish were White Perch (*Morone americana*), Threespine Stickleback (*Gasterosteus aculeatus*), Tubenose Goby (*Proterorhinus marmoratus*), Alewife (*Alosa pseudoharengus*), Ruffe (*Gymnocephalus cernua*), Rainbow Smelt (*Osmerus mordax*), and Sea Lamprey (*Petromyzon marinus*) combined. However, fish were not the only invasive species encountered. Occurrences of invasive faucet snail (*Bithynia tentaculata*) became noticeable in 2014, and we found that the faucet snail data collect by the Great Lakes Coastal Wetland Monitoring Project were largely new observations. These, and other invasive species records, are now available on the USGS Nonindiginous Aquatic Species website (https://nas.er.usgs.gov/).

The past five years of field work was not without challenges. In June of 2011 the NRRI field team participated in a project-wide sampling standardization training, which was administered to all regional teams by project leaders. However, after the 2011 field season we realized more discussion was needed to ensure methodology and interpretation of sampleable vegetation zones were consistent among regional teams. *Phragmites* (*Phragmites australis australis),* was one such example. The new growth of *Phragmites* has sharp leaves and often emerges among the dead stems from previous years, which remain strong and sharp. The NRRI field team found mixed densities of *Phragmites* in wetlands of Green Bay, WI in 2011, and some were so dense they could not be penetrated without risking injury, or doubt in the quality of the data collected. Over several years of sampling wetlands in Green Bay, WI we have seen herbicide treatments target and kill *Phragmites*. Sometimes the spraying was followed by mowing the dead *Phragmites* stalks, as was observed at site 1697 (Figure 23). As it turns out, a *Phragmites* zone can take many forms, and we took steps to ensure all fish/bug teams were making the same sampling decisions based on safety and data quality.

Figure 23. *Phragmites* at site 1697 killed by herbicide in 2013 and then mowed. Green Bay is visible in the background. NRRI photo.

The most logistically-challenging sample year was in 2012 when the NRRI field team traveled to Isle Royale with a target of reaching 5 sites during a 9-day excursion. Two sites were sampled for fish, macroinvertebrates, and water quality; one site was only sampled for macroinvertebrates and water quality (the field crew hiked overland several hours to reach the wetland); one site was rejected for lack of Lake Superior influence; and one site could not be reached. Transporting personnel and field equipment proved to be formidable challenge, which was exacerbated when the crew's 18' workboat was severely damaged and rendered inoperable while docked during a storm. Field activities for fish, macroinvertebrate, and water quality sampling are logistically difficult to coordinate on Isle Royale because of the long distances between sheltered bays around the Island, the amount of bulky field equipment required to transport, and the limited transportation options. Nevertheless, the NRRI field crew was able to collect valuable data and learned important lessons about coordinating future field endeavors at Isle Royale. One of the unique finds on Isle Royale was the presence of a the mayfly *Siphloplecton* (Figure 24) unique to this island, as it was not found anywhere else in the Great Lakes basin by other fish/bug teams. Between 2011 and 2015 the NRRI field team has collected 769 individual macroinvertebrate samples for the Coastal Wetland Monitoring Project, which is an average of 154 samples per year.

Figure 24. Image of *Siphloplecton* (Order Ephemeroptera, Genus *Baetidae*) collected by the NRRI field team in 2012 from wetlands surrounding Isle Royale, MI (upper). Genus *Siphloplecton* has only been found at Isle Royale, and is distinguished from other more common *Baetidae* by their bifurcated tarsal claw (lower). NRRI photos.

The NRRI field team has encountered several other rare or interesting species in wetlands of the Great Lakes. In Green Bay, WI the NRRI field team began noticing some gar that resembled

Spotted Gar, but turned out were likely Longnose x Shortnose Gar hybrids (*Lepisosteus osseus x L. platostomus*). The identity of these fish had been recently corroborated by WI DNR. This seems to be a local phenomenon unique to Green Bay because fish captured outside this region do not express hybrid morphologic traits. In 2014 at another wetland in Green Bay, WI a Longear Sunfish (*Lepomis megalotis*) was discovered; these are listed as a **threatened species** in Wisconsin.

An interesting fyke net bycatch from 2014 was the capture of a spiny softshell turtle *(Apalone spinifera)* (Figure 25) at a wetland within the St. Louis River Estuary, which is an Area of Concern (AOC) for contaminated sediments and several other Beneficial Use Impairments. Efforts are ongoing to delist the St. Louis River as an AOC, and the presence of spiny softshell turtles is a good indicator that some areas of the St. Louis River may be recovering. While not a threatened or endangered species, spiny softshells are rarely captured, as this turtle was the only individual found in five years of CWM sampling across all fish/macroinvertebrate teams. Another notable observation was made at two wetlands sampled as special request by WI DNR within the Menominee River harbor area of Marinette, WI. The fish survey revealed species common to the area, but field staff noticed an uncommonly-high density of large bryozoan colonies (Figure 26). While a unique finding, the significance of this observation is unknown.

Figure 25. Spiny softshell turtle (*Apalone spinifera*) collected in a fyke net at a site within the St. Louis River, WI Area of Concern (AOC). NRRI photo.

The NRRI field team has solidified several new partnerships as a result of the Coastal Wetland Monitoring Project. We have collaborated several times with the Bad River and Redcliff Bands of Lake Superior Chippewa, as well as the Keweenaw Bay Indian Community, for permission to access wetlands and share collected data. We have developed collaborations or leveraged spin-off projects with several entities, including Wisconsin Department of Natural Resources, The Nature Conservancy, landowners surrounding the Bay Shore Blufflands State Natural Area (WI), National Park Service-Great Lakes, Wisconsin Nature Conservancy, and Environment Canada. Coastal Wetland Monitoring data were used in 10 presentations by lead authors Brady and Dumke between 2013 and 2015, which raised awareness of the CWM project to hundreds of wetland managers, researchers, and policy makers. WI DNR also contracted NRRI to create a report that would compare wetlands around Clough Island (within the St. Louis River Estuary AOC) with neighboring wetlands outside the AOC. This report was based on Coastal Wetland Monitoring field data.

Figure 26. NRRI field technician Nick Winter holding a bryozoan colony attached to a cattail stalk at site 7067. Large bryozoan colonies were common at site 7067 and neighboring site 7068. NRRI photo.

Central Basin Regional Team: Don Uzarski, Dennis Albert (Vegetation), Thomas Gehring and Robert Howe (Birds and Amphibians), Carl Ruetz (Fish), and Matt Cooper (Macroinvertebrates)

Central Basin Fish/Invertebrate/Water Quality Summary Report – 2011-2015

The Central Basin Fish, Invertebrate, and Water Quality team consisted of Central Michigan University, Lake Superior State University, Grand Valley State University, and the University of Notre Dame. Sites sampled included coastal wetlands on lakes bordering the Lower Peninsula of Michigan, eastern Upper Peninsula of Michigan, western Upper Peninsula of Michigan, and Lake St. Clair.

In total, 211 wetland sites were visited over the summers of 2011-2015, of which 10-13 sites were considered benchmarks and sampled annually. Some sites were rejected due to not meeting the criteria of a sample-able wetland as described by the SOP, private land owners not allowing access to sites via land, inclement weather impeding boating to the site, and logistic issues such as distance to the nearest boat launch (for access via water). A total of 304 dominant vegetation zones were sampled for water quality and invertebrates from 2011-2015. Two hundred and fourteen of these zones included fish community samples. Zones that were not sampled for fish fell below the 20 cm minimum water depth.

In 2013, “Sugar Island wetland #3” was added as a benchmark to characterize changes in fish communities and was sampled continuously by the LSSU sampling crew. Continued monitoring of this site before and after restoration helped to identify changes to existing wetlands and to their use by fishes and other aquatic organisms at various life stages.

No expansions of the invasive species European frog-bit (*Hydrocharis morsus-ranae*) were documented in either Lake Michigan or Lake Superior. However, the LSSU fish and invertebrate crew identified a large patch of frog-bit at Raber Bay Wetland. Raber Bay Wetland is located in the St. Mary’s River, Lake Huron watershed. The LSSU crew worked with the East Mackinac/Chippewa/Luce County Conservation District to initiate a response to the invasion. Over 600 lbs. of frog-bit was hand-pulled from the Raber Bay Resort boat launch in an effort to minimize spread throughout the river (Figure 27).

Figure 27. LSSU fish and invertebrate sampling crew helped hand-pull the invasive European frog-bit after they discovered it at a boat launch near a wetland they were sampling in northern Michigan.

Central Basin Amphibian & Bird Summary – 2011-2015

The Central Basin Amphibian and Bird Team sampled amphibians and birds in coastal wetlands on lakes bordering the Lower Peninsula of Michigan, eastern Upper Peninsula of Michigan, and sites in western Lake Erie, Ohio, during summers 2011-2015.

In total, 199 wetland sites (of which 10-12 were benchmark sites sampled each year) were surveyed. Of the original number of wetlands assigned to sample, 4 sites were web-rejected or visit-rejected, 34 sites were not sampled because they could not be accessed safely for night sampling, and 18 sites were not sampled because private landowners would not grant access.

Twelve of the 13 anuran species monitored at our sites were detected. No mink frogs were detected at any wetlands surveyed. Fowler's toad and pickerel frogs were detected at only 1 site each. Northern cricket frogs were detected at 3 sites.

One hundred and forty-one bird species were detected at our wetland sites. Black-billed cuckoos, yellow-billed cuckoos, and yellow-headed blackbirds were detected at only 1 site each. Black terns were detected at 4 sites. Among focal bird species, we recorded pied-billed grebes at 25 sites, Virginia rails at 19 sites, Sora at 9 sites, least bitterns at 8 sites, common moorhens at 7 sites, American coots at 5 sites, and American bitterns at 4 sites. No king rails were detected.

Central Basin Vegetation Summary Report – 2011-2015

The Central Basin Vegetation Team, consisting of vegetation expert Dr. Dennis Albert and crew members from both Oregon State University and Central Michigan University, sampled a total of 241 sites located on Lakes Superior, Michigan, Huron, St. Clair, Erie and the St. Mary's River. Of these sites, 12-14 were benchmarks and sampled annually.

Vegetation teams coordinated with the Fish/Invertebrate/Water Quality teams to complete sampling at island sites. Those sites which could not be reached were those that were not accessible by land due to private land owners not granting access, inclement weather impeding the complete sampling of transects, or lack of inundated vegetation. Further, at various sites, recent herbicidal treatments had restricted access for sampling.

Important Central Basin vegetation sampling results from 2011-2015

Phragmites and Other Invasive Vegetation:
Signs of invasive *Phragmites australis* treatment with herbicides were seen at several sites in (2012) in Saginaw Bay, Lake Huron, and Lake Erie. In 2013, new populations of *Phragmites australis* were found near Cheboygan on Lake Huron and locational data was shared with Michigan's Invasive Species Information Network (MISIN) and Rapid Response Team.

In 2012 we further documented the expansion of the invasive species frog-bit (*Hydrocharis morsus-ranae*). The plant is now well established in western Lake Erie, Lake St. Clair, and the St. Mary's River. In 2013, detailed locational data for the invasive species frog-bit (*Hydrocharis morsus-ranae*) was also provided to the team to allow them to plan future herbicide or removal treatments. No expansions of the invasive species frog-bit (*Hydrocharis morsus-ranae*) were documented in either Lake Michigan or Lake Superior in 2015.

In 2014, another invasive species, *Lythrum salicaria* (purple loosestrife), established aggressively following treatment for *Phragmites* at one Saginaw Bay site, and less aggressively at a second site. Algae blooms were extensive at both sites, and at the one site where below-ground biomass was examined, there appeared to be mortality of native emergent vegetation as well as *Phragmites*. Both native perennials and invasive *Phragmites* re-established in the treated stands two or three years following treatment.

By 2014, mowing and *Phragmites* treatment by private landowners continued to be documented at sites on Lake Huron, the St. Mary's River, and Lake Michigan. Throughout 2011-2015, sampling was incomplete or partial at these heavily managed sites, as land owners were often unwilling to allow samplers access to the shorelines.

Rare Plants:

In 2012, at least three western Lake Erie marshes had populations of rare plants: populations of *Nelumbo lutea* (American lotus) and *Sagittaria montevidensis* (Montevidense's arrowhead). Throughout 2011-2015, several orchids were found in the coastal wetlands, including Loesel's twayblade (*Liparis loeselii*), rose pogonia (*Pogonia ophioglossoides*), grass-pink (*Calopogon tuberosus*), and hooded ladies'-tresses (*Spiranthes romanzoffiana*). None of these orchids are federally or state listed species, but as orchids they have protection from commercial harvest under state regulations. In 2015, however, orchids were less abundant than in past years because of high water levels.

In 2015, the Central Basin Vegetation team found a high quality Lakeplain Lake Prairie complex, a rare plant community throughout the Great Lakes region, during a plant survey of St. Johns marsh in an area that had been proposed for a dike enhancement project by the Michigan DNR (Figure 28). The site contains abundant milkweed plants, which appear to include both common milkweed (*Asclepias syriaca*) and possibly a rare Sullivant's milkweed (*A. sullivantii*), both of which were being used by monarch butterflies. The survey has resulted in ongoing discussions concerning the proposed boundaries of the project.

Figure 28. GLRI sampling site at Benchmark site #432 (St. Johns Marsh), July 23, 2015.

One rare plant, Houghton's goldenrod (*Solidago houghtonii*) was encountered on a large stretch of privately owned shoreline along the northern shore of Lake Michigan, but no plants occurred in any of the sampling plots.

Wetland Disturbances:

In 2012, a comparison of St. Mary's River data from 1987 through 1990s to available data from the previous two years of sampling indicated that the extended low water conditions has resulted in loss of relatively extensive emergent marsh beds along Lake Nicolet and possibly other nearby areas.

Throughout annual sampling, plowing and mowing was documented at sites on Lake Huron, the St. Mary's River, and Lake Michigan. Plant diversity appeared to be greatly reduced by plowing, but was more difficult to evaluate with mowing, as several species can be identified to genus, but not species, as they are immature or flowers have been cut off. However, in 2015 sites with ongoing mowing and *Phragmites* treatment by private landowners were greatly reduced in 2015 due to high water levels. The meter increase in water depth in 2014 and 2015 resulted in wide-scale erosion of many wetland macrophytes, including shrubs. These plants formed a significant wrack along the shore of many of the sampled marshes. Bulrush species

(*Schoenoplectus pungens* and *S. acutus*) were much less prone to damage than more shallow rooted plants. Changes to coastal wetland vegetation related to water level fluctuation such as those witnessed in 2014 and 2015 represent a very important mechanism that maintains the diversity and function of Great Lakes coastal wetlands.

Eastern U.S. Regional Team: **Douglas Wilcox (Vegetation), Chris Norment (Birds and Amphibians), James Haynes (Fish), and Gary Neuderfer (Macroinvertebrates)**

Eastern Basin Vegetation Summary Report – 2011-2015

The College at Brockport surveyed the plant community at 124 wetlands from 2011-2015, which includes sites that were repeated as either designated repeat sites or because they received a benchmark tag. These sites were located on the southern shores of Lakes Erie and Ontario between Erie, Pennsylvania, to Belleville, Ontario, with the vast majority of these sites on Lake Ontario. There was little variation between sites and between years, with no change in Mean-C values across years (Figure 29).

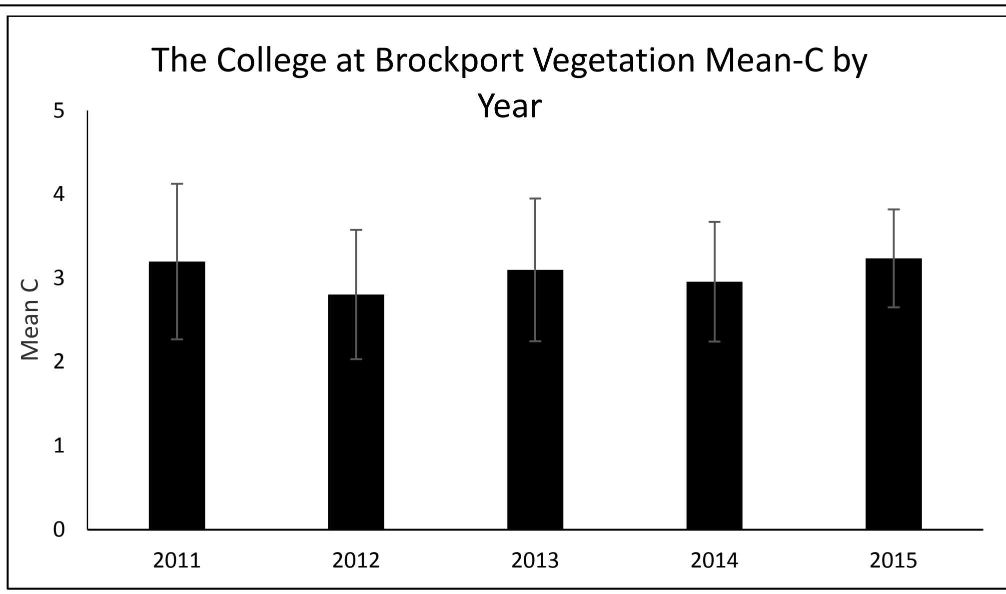

Figure 29. Average Mean-C for sites sampled by The College at Brockport from 2011-2015.

Similarly, invasive cattail dominance (combined *Typha x glauca* and *Typha angustifolia*) remained relatively stable and dominant across years and was typically ~35% of emergent plant community (Figure 30).

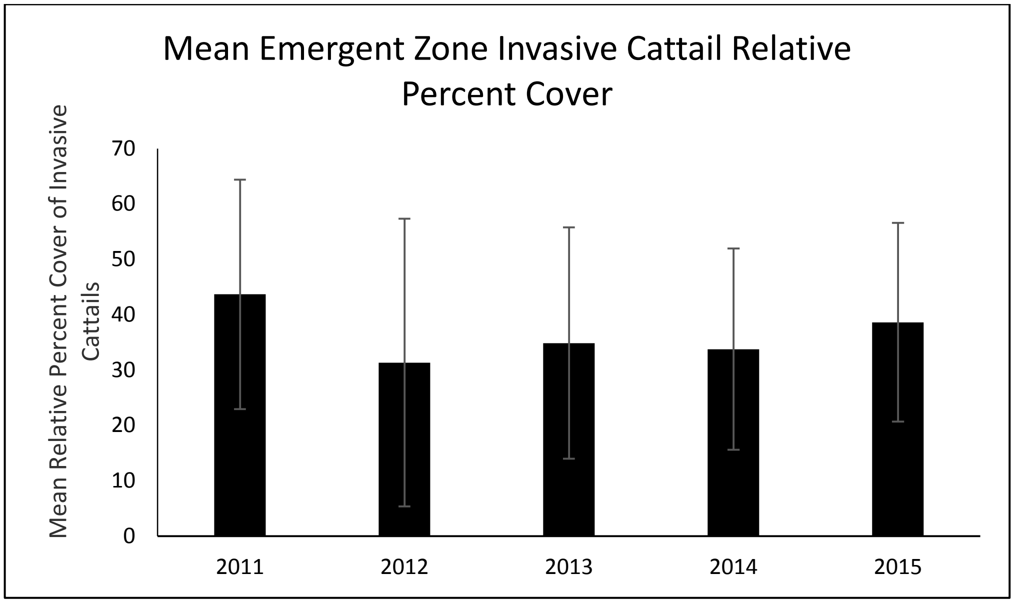

Figure 30. Mean invasive cattail cover of vegetation sites sampled by The College at Brockport from 2011-2015, represented as a percentage of the summed plant cover by site.

Finally, The College at Brockport tracked the distribution and spread of the invasive water chestnut from 2011-2015 (Figure 31).

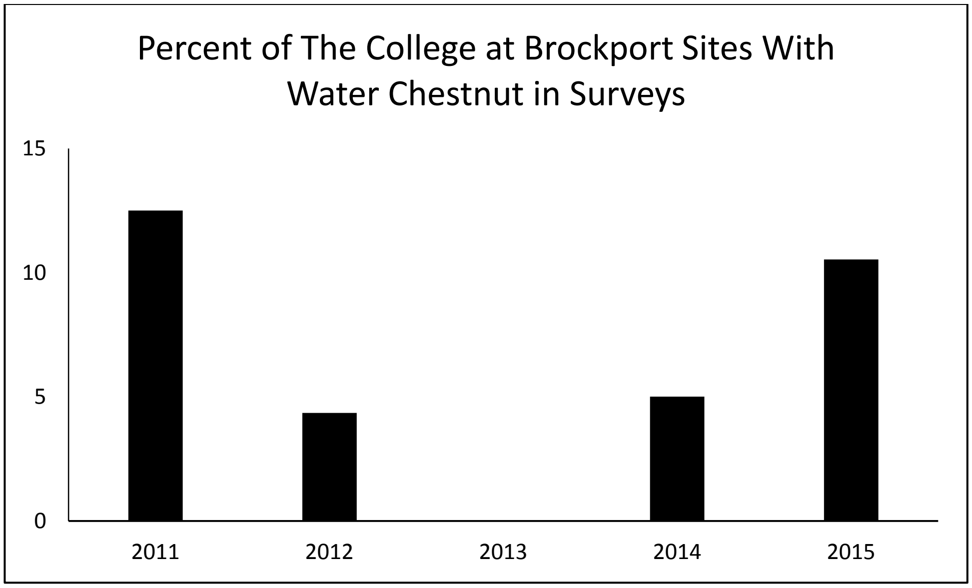

Figure 31. Percent of vegetation sites sampled by The College at Brockport from 2011-2015 that had water chestnut (*Trapa natans*) in official surveys. Note, this does not include sites where water chestnut was found on-site but not in quadrats.

While the data collected and resulting figure do not show an increase in water chestnut infested sites across years, The College at Brockport did note an increasing regional spread outside of official survey quadrats across years. The College at Brockport noted little change in species richness of wetlands sampled from 2011-2015, with a small and insignificant decrease in native species richness and no change in invasive richness (Figure 32).

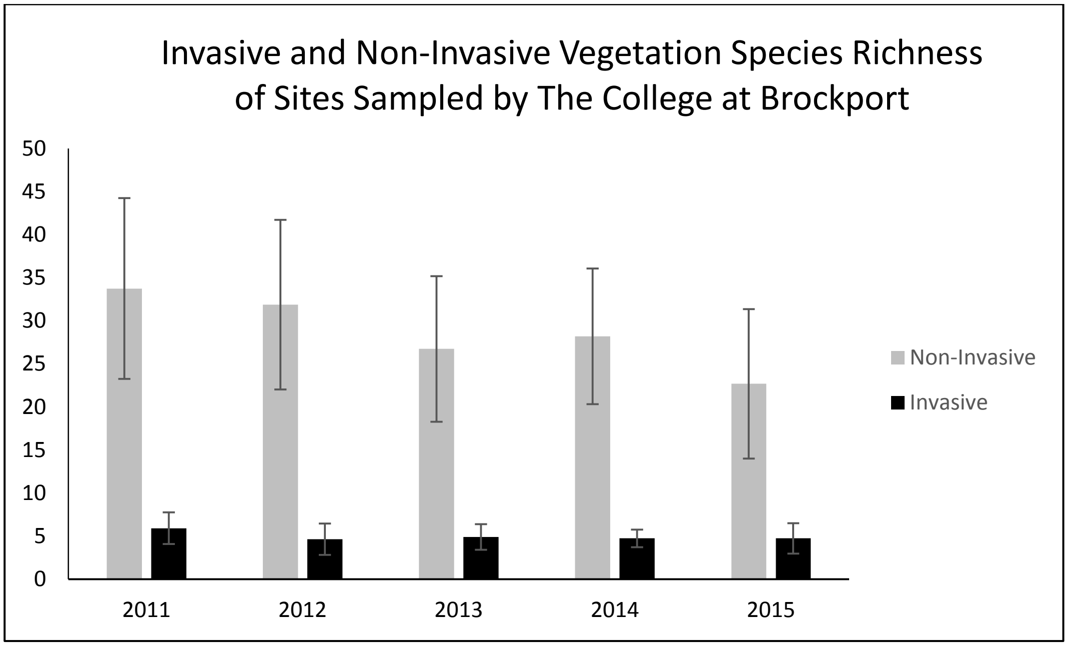

Figure 32. Mean invasive and non-invasive plant species richness of wetlands sampled by The College at Brockport from 2011-2015.

Eastern Basin Fish and Macroinvertebrate Summary – 2011-2015

The College at Brockport surveyed the fish community in 109 sites from 2011-2015, with the majority of these sites located on the south and east shores of Lake Ontario and fewer than five on eastern Lake Erie. A total of 157 vegetation zones were sampled across the five years, for a mean of 1.44 fishable zones per site (Table 18). A total of 35,481 fish were captured and identified across the five years, for a mean of 75.33 fish per net-night. The vegetation zone that yielded the greatest number of fish across the five years was the submerged aquatic vegetation zone (SAV) with 23,541 fish, largely due to the fact that it was the most commonly fished zone. Lily was the second most fished zone but yielded only 2,865 fish across the five years and had the second lowest catch per net-night, 25.8. The zone with the greatest catch per net-night was open water, with 230.5 fish per net-night. However, this number was greatly inflated by one site, Sherwin Bay (site 157), that yielded 5,160 fish across three nets in 2013. Removing this one zone lowers the open water catch per net-night to 53.0, more in line with the overall catch rate of 75.3.

Table 18. Total fish catch across zones and years, number of zones sampled, and mean catch per net-night of fish sites sampled by The College at Brockport from 2011-2015.

Zone	2011	2012	2013	2014	2015	Total Catch	# of Zones	Catch per Net-Night
SAV	10,168	6,520	1,736	874	4,243	23,541	89	88.2
Open Water		188	5,160		183	5,531	8	230.5
Lily	336	1,068	428	612	421	2,865	37	25.8
Dense bulrush	194		813	131	280	1,418	6	78.8
Peltandra / Pontedaria	961	99		90		1,150	8	47.9
Typha	203	342	17			562	3	62.4
Sparse bulrush	47	351				398	5	26.5
Wild rice				16		16	1	5.3
Total	**11,909**	**8,568**	**8,154**	**1,723**	**5,127**	**35,481**	**157**	**75.3**

The majority of fish caught by The College at Brockport were classified as Young-of-Year (YOY), making up 70.3% of the five-year total catch (Table 19). The zone containing the greatest amount of YOY was open water, at 93.8% YOY. However, this number was inflated again by one anomalous site, Sherwin Bay, whose 5,160 fish were almost all YOY. Dense bulrush was the zone with the second greatest YOY percentage at 82.4. The SAV zone, the zone that yielded the most total fish, was 68.2% YOY. Wild rice contained the lowest percentage of YOY at 6.3%; however, The College at Brockport only fished this zone once in five years.

Table 19. Percent of the total fish catch as "Young-Of-Year" across vegetation zones and years at sites sampled by The College at Brockport from 2011-2015.

Zone	2011	2012	2013	2014	2015	Total
Open Water		46.8	96.1		77.6	93.8
Dense bulrush	56.2		89.3	89.3	77.1	82.4
Peltandra / Pontedaria	84.4	35.4		22.2		75.3
SAV	58.2	77.1	55.3	54.8	86.6	68.2
Typha	6.9	84.5	76.5			56.2
Lily	13.1	40.4	42.1	47.2	70.8	43.4
Sparse bulrush	19.1	25.6				24.9
Wild rice				6.3		6.3
Total	**58.0**	**69.6**	**83.8**	**52.6**	**84.5**	**70.3**

Eastern Basin Water Quality Summary Report – 2011-2015

Chloride ion, chlorophyll a, total nitrogen, and total phosphorus concentrations were consistently lowest in lacustrine sites sampled by The College at Brockport, averaging 23.63, 4.7, 0.478, 0.042 mg/L, respectively, from 2011-2015 (Table 20). Riverine sites had the greatest chloride ion, total nitrogen, and total phosphorus concentrations, averaging 48.11, 0.841, and 0.109 mg/L, respectively. Barrier-protected sites had the greatest chlorophyll a concentrations, with an average of 13.5 mg/L from 2011-2015.

Table 20. Mean chloride ion (mg/L), chlorophyll *a* (µg/L), total nitrogen (mg/L), and total phosphorus (mg/L) of barrier protected, lacustrine, and riverine sites sampled by The College at Brockport from 2011-2015, including yearly and hydrogeomorphic means.

		Chloride Ion (mg/L)	Chlorophyll *a* (µg/L)	Total N (mg/L)	Total P (mg/L)
Barrier Protected	2011	37.03	14.1	0.771	0.121
	2012	19.42	17.8	0.860	0.054
	2013	51.18	5.8	0.763	0.035
	2014	66.98	11.1	0.861	0.075
	2015	69.98	12.1	0.912	0.104
	Mean	**42.25**	**13.5**	**0.831**	**0.081**
Lacustrine	2011	26.29	1.5	0.452	0.040
	2012	22.17	6.3	0.367	0.037
	2013	22.63	4.2	0.395	0.028
	2014	24.38	9.3	0.558	0.053
	2015	21.63	2.9	0.562	0.040
	Mean	**23.63**	**4.7**	**0.478**	**0.042**
Riverine	2011	31.21	6.7	0.720	0.079
	2012	81.16	11.8	0.807	0.127
	2013	43.36	7.2	0.993	0.099
	2014	43.25	6.4	0.790	0.096
	2015	48.94	4.7	0.916	0.152
	Mean	**48.11**	**7.5**	**0.841**	**0.109**
Overall Mean		**40.81**	**8.8**	**0.756**	**0.085**

Dissolved oxygen, temperature, and pH, all replicate-level water quality measurements, were greatest in lacustrine sites sampled by The College at Brockport from 2011-2015 (Table 21). Specific conductance, the final replicate-level parameter in Table 4, was greatest in riverine sites, with a mean of 433.54 µS/cm.

Table 21. Mean dissolved oxygen (mg/L), temperature (C), pH, and specific conductance (µs/cm) of barrier protected, lacustrine, and riverine sites sampled by The College at Brockport from 2011-2015, including yearly and hydrogeomorphic means.

		Dissolved Oxygen (mg/L)	Temperature (C)	pH	Specific Conductance
Barrier Protected	2011	5.48	23.2	7.18	449.70
	2012	6.65	26.3	7.72	235.10
	2013	4.25	25.5	7.82	438.83
	2014	4.23	22.8	6.81	471.14
	2015	5.06	22.6	7.64	497.27
	Mean	**5.48**	**24.3**	**7.29**	**391.84**
Lacustrine	2011	8.41	25.8	7.65	323.08
	2012	8.26	27.4	8.21	293.30
	2013	8.49	23.8	8.48	315.51
	2014	6.73	24.5	7.32	275.93
	2015	5.59	23.7	7.93	277.41
	Mean	**7.32**	**25.2**	**7.65**	**294.03**
Riverine	2011	7.08	25.5	7.53	385.17
	2012	6.02	24.6	7.85	547.29
	2013	6.45	24.3	7.91	468.80
	2014	3.98	21.4	6.88	397.21
	2015	8.25	22.3	7.52	375.81
	Mean	**6.36**	**23.8**	**7.40**	**433.54**
Overall Mean		**6.31**	**24.2**	**7.41**	**389.77**

Working with Partners

The College at Brockport worked with many state, federal, and non-profit conservation organizations from 2011-2015 by sampling sites under the “benchmark” tag and sharing data. Braddock Bay (site 7052) received a benchmark tag from 2012-2015 to help generate pre- and post-restoration data for a large GLRI-funded restoration project by the US Army Corps of Engineers. The Corps is using all data we generated from that site, as their restoration will impact the water quality, vegetation structure and associated wildlife use, and fish movement and spawning patterns in the bay. Buck Pond and Buttonwood Creek, sites 51 and 7026, received benchmark tags from 2013-2015 for additional sampling on behalf of Ducks Unlimited. Ducks Unlimited has used data generated from bird, amphibian, fish, and vegetation sampling to help determine the effectiveness of their channel and pothole creation, cattail control, and sedge/grass meadow plantings. Long Pond, Buck Pond, and Salmon Creek, sites 29, 51, and 26, were sampled under the benchmark tag in 2015 to generate additional pre-restoration data for the US Fish and Wildlife Service (USFWS) restoration project that began in 2016. Much like Ducks Unlimited, the USFWS is primarily interested in vegetation, bird, amphibian, and fish data from these sites as their restoration is focused on improving wildlife habitat by altering the vegetation. All of these aforementioned restoration projects have occurred in the Rochester Embayment Area of Concern, and all are being performed using GLRI money in an attempt to delist the AOC, primarily by addressing the Beneficial Use Impairment of degraded fish and wildlife habitat.

Outside of the Rochester AOC work, The College at Brockport has sampled wetlands for The Nature Conservancy in relation to some of their restoration work. Floodwood Pond (site 7024) on the eastern shore of Lake Ontario was sampled as a regular site in 2011 and again as a benchmark in 2013 to generate pre- and post-restoration data to determine what effect the restoration had on the spawning fish community. Third Creek (site 63) was sampled as a benchmark in 2011 to generate baseline data for The Nature Conservancy as they just acquired the site and wanted to know the wetland's condition.

The College at Brockport has shared all data generated with state-level conservation authorities that own some of the wetlands that we sampled. These agencies include the New York Department of Environmental Conservation and New York State Parks, Recreation, and Historic Preservation Department. These agencies require access permits before research crews are allowed on their property and have a data-sharing clause as part of the permits. The biologists in charge of these properties have used these data to help make management decisions, track invasive spread, and find rare or threatened species on their property.

The College at Brockport has been active in sharing data pertaining to invasive species distribution and abundance across Lake Ontario to various conservation authorities. For example, The College at Brockport has shared all site-level invasive species presence data with NY-iMapInvasives, an online database and mapping website that is managed through a partnership between the New York Natural Heritage Program and the New York Department of Environmental Conservation. All invasive presence data, including vegetation, fish, bird, and aquatic macroinvertebrate, have been shared on this database. Additionally, The College at Brockport has proactively communicated with the local offices of the New York Department of Environmental Conservation and the New York State Partnership for Regional Invasive Species Management on new and expanding invasive species distributions. The most notable species has been water chestnut (*Trapa natans*), which has gone from being locally isolated near Sodus Bay in 2011 to now spanning much of the southern and eastern shoreline of Lake Ontario. This communication between the Great Lakes Coastal Wetlands Monitoring Project and local authorities has allowed a number of small infestations to be eradicated before they became a full invasion.

Jobs and Academics

The College at Brockport employed 20 different students from 2011-2015 to perform bird, amphibian, fish, water quality, aquatic macroinvertebrate, and vegetation sampling. Most students choose to return for at least one year as a way to get more work experience, which has helped in limiting the need to train new workers continually. Also, three students that began on the project as undergraduate assistants stayed on the research crew as graduate students in succeeding years. Three of the graduate students that were employed on the Brockport crew have successfully defended masters theses using data generated from the project, with another three theses in progress to be defended. Finally, one soft-money research scientist position has been supported for 10 months per year from 2011-2015 with funding from this project.

Canadian and US Western Lake Erie Regional Team: Jan Ciborowski, Joseph Gathman, Katya Kovalenko (Water Quality, Fish and Macroinvertebrates), Janice Gilbert (Vegetation), Doug Tozer (Birds and Amphibians), and Greg Grabas (north shore of Lake Ontario – Water Quality, Fish, Macroinvertebrates, Vegetation)

Canadian Team Bird/Amphibian Summary Report – 2011-2015

Bird and amphibian field crews evaluated 300 sites that had been selected and ordered for potential sampling in 2011-15, located almost entirely on the Canadian shores of Lake Huron, Erie, and Ontario (and a few sites sampled in Michigan and Ohio waters of Lake Erie in 2011). Of these, ~15% were not surveyed because access was unobtainable (despite extensive efforts by surveyors) or because the site did not meet the project’s criteria for sampling. The remainder was not surveyed because the site was beyond sampling capacity. Two hundred and eight sites were visited (each on 5 occasions) and sampled for amphibians and birds.

Of note were 242 point occurrences of 15 Ontario bird species at risk observed in 2011-15. This is a substantial number of point occurrences observed over the duration of the 5-year project and adds significantly to the Province of Ontario’s natural heritage inventory of at-risk species, maintained by the Natural Heritage Information Center of the Ontario Ministry of Natural Resources and Forestry (Table 22).

Table 22. Ontario avian at-risk species observed from 2011-2015.

Species	ESA/SARA Status*	No. Occurrences 2011-15
Acadian Flycatcher	endangered	1
American White Pelican	threatened	1
Bald Eagle	special concern	14
Bank Swallow	threatened	34
Barn Swallow	threatened	126
Black Tern	special concern	12
Bobolink	threatened	1
Canada Warbler	threatened	1
Chimney Swift	threatened	22
Common Nighthawk	threatened	2
Eastern Meadowlark	threatened	3
King Rail	endangered	2
Least Bittern	threatened	24
Peregrine Falcon	special concern	1
Red-headed Woodpecker	threatened	1
Total		**242**

* Status is the assessment of greatest concern based on Ontario's Endangered Species Act (ON-ESA) or Canada's Species at Risk Act (SARA).

Also of note were 33 occurrences of Chorus Frog in 2011-15, which is listed as threatened in Canada.

Canadian Team Fish and Macroinvertebrate Summary Report – 2011-2015

The CWS crew visited and evaluated 7-10 locations annually along the north shore of Lake Ontario, and up to 3 in Lake Huron to balance effort among sampling crews (Brockport and University of Windsor teams).

The University of Windsor crew was initially assigned 36-40 sites annually on lakes Erie and Huron or the connecting channels. Each year a number of sites were not sampled. Some sites were on aboriginal land and we could not make contact to receive permission to sample. Other reasons for not sampling included remoteness from a boat ramp, lack of suitable vegetation zones to meet invertebrate or fish sampling criteria, or an inability to contact owners of private land. Ultimately, the University of Windsor and Canadian Wildlife Service together visited between 35 and 38 sites annually. Catches varied from almost 5,000 fishes (2012) to over

10,000 (2015). All specimens were released except for a few dozen voucher specimens retained annually. Between 46 and 57 fish species were captured each year (Table 23).

Table 23. Summary of annual fishing effort and catches of species and specimens by University of Windsor and Canadian Wildlife Service crews.

University of Windsor					
Year	2011	2012	2013	2014	2015
Sites visited	25	26	28	25	27
Sites fished	22	19	17	19	25
No. spp	47	37	52	49	48
No. Specimens	4744	1858	3185	1661	5765

Environment Canada - Canadian Wildlife Service					
Year	2011	2012	2013	2014	2015
Sites visited	10	10	10	11	11
Sites fished	10	9	9	10	10
No. spp	36	32	34	38	36
No. Specimens	4640	3125	4295	4488	4469

UW & CWS combined					
Year	2011	2012	2013	2014	2015
Sites visited	35	36	38	36	38
Sites fished	32	28	26	29	35
No. spp	50	46	56	56	57
No. Specimens	9384	4983	7480	6149	10234

The sampling effort summarized in Table 23 represents perhaps the most comprehensive undertaking to sample the range of Great Lakes coastal wetlands ever undertaken in Canada. In addition to providing scientifically-sound estimates of the distribution and abundance of common wetland species, we were able to document occurrences of both species at risk and aquatic invasive species. University of Windsor and Canadian Wildlife Service sampling produced significant range extensions or additional records of Spotted Gar, Pugnose Minnows, Round Gobies and Tubenose Gobies, and a record of a Grass Pickerel (in Georgian Bay - the first since the 1980s).

The 2011-2015 sampling events have been undertaken during a period of dramatic changes in Great Lakes water levels. Over the 5-y period of the project, Lake Huron water level has risen by over 1 m, and has been above the long-term (98-year) average, according to NOAA data.

Although the peak fell well short of some earlier high-water periods of previous decades, the present situation is unusual in that it was preceded by almost fifteen years of sustained below-average lake levels. During this period, wetland vegetation zones gradually shifted their positions down the shoreline elevation gradient. Now, lake level is rising again, but the vegetation has not had time to fully respond by shifting back up-slope. As a result, field crews *encountered deeply flooded wet meadows (greater than 0.5 m in depth). Fishing in these areas* was often hampered by the presence of shrubs, now dead and dying under the changing hydrologic regime. A further result is that the lower edges of sedge meadows have started receding, leaving open areas between the meadow and next vegetation zone down-slope (bulrush or cattail) which had not colonized the meadow-abandoned areas. As for these down-slope zones, the water depth in many is now great enough to make them too deep (>1 m) to allow fyke nets to be deployed. Nevertheless, the stratified, repeated-sampling design of the CWM program allows us to track year-to-year variation in wetland communities and is providing unparalleled opportunity to observe the biological variation associated with cyclic changes in water levels of Great Lakes coastal wetlands. We will also be able to document whether resilience (the ability of communities to recover from marked natural and human-caused perturbations) of wetlands whose boundaries are limited by coastal structures differs greatly from the resilience of unconstrained wetlands.

<u>Reptiles</u>

The Canadian Wildlife Service is responsible for developing recovery strategies and management plans for turtle species listed as at risk in Canada. As required under the Species at Risk Act (SARA), critical habitat is a required component of the Recovery Strategy for four at risk turtles: Blanding's Turtle (*Emydoidea blandingii*), Eastern Musk Turtle (*Sternotherus odoratus*), Spotted Turtle (*Clemmys guttata*), and Spiny Softshell Turtle (Apalone spinifera). Critical habitat is based on the suitable habitat where turtles have been observed. Examples of suitable habitat are wetlands and watercourses such as marshes, rivers, and some lakes. Incidental observations from the Great Lakes Coastal Wetland Monitoring project as well as other sources of turtle observations have identified many suitable habitat locations for proposal as candidate critical habitat for species specific recovery strategies. The data provided were invaluable in identifying additional critical habitat sites.

Canadian Team Vegetation Summary Report – 2011-2015

Vegetation surveys were conducted by expert botanists Janice Gilbert (returning each year since 2011), Dan Barcsza (2012-2014) and Carla Huebert (annually, beginning in 2013). For the CWS crew, Greg Grabas led the vegetation sampling and identification and was assisted by various summer students and Canadian Wildlife Service personnel. Vegetation was surveyed at all sites visited annually by University of Windsor and Canadian Wildlife Service crews ('sites visited' in Table 23).

The 2015 season represented a year in which lake levels have risen significantly after a prolonged period of low water. This has produced some interesting findings. For example, water levels appear to have changed more rapidly than has the distribution of the aquatic plants normally characteristic of particular depth zones. Furthermore, the sampling designs of macrophytes, invertebrates and fishes are all tied to the locations of zones and classes of emergent vegetation. It was sometimes difficult to delineate between vegetation zones, as the emergent species that normally are found in monoculture were often found mixed with other species. Also, because many of the meadows were flooded, plants that are normally observed growing in the emergent and submergent zones were present deep in the meadow zone, and sedges and other meadow species could be found growing far out into what should be the emergent zone.

With new knowledge of the presence of Starry Stonewort (*Nitellopsis obtusa*) in the Lower Great Lakes, surveyors made extra effort to look for and positively identify this non-native macroalgae during wetland surveys. In total, 8 of 11 Lake Ontario wetlands sampled contained *Nitellopsis*. All wetlands with positive records were located in eastern Lake Ontario, which has been shown to have both a greater areal extent of wetland habitat and higher IBI scores than western portions of Lake Ontario.

Canadian Wildlife Service had previously identified *Nitellopsis* in Canadian portions of Lake St. Clair and the Detroit River. In 2016, *Nitellopsis* was also found in a number of transects at a Michigan location bordering on Lake St. Clair (site 428 - Black Creek Wetland). It was growing in sandy substrates and in several spots it was so dense that it covered most of the water column, from substrate to surface, well over one m thick. *Nitellopsis* achieves similar densities at locations in eastern Lake Ontario.

The associations between *Nitellopsis* and other biota (invertebrates, fishes) are starting to be qualitatively investigated, but it may be several years before its impact on habitat use is understood. However, *Nitellopsis* can occupy the entire water column in areas that are 2 m deep or more. Consequently, it has potential to influence organisms both directly, and indirectly by influencing water flow.

With the recent arrival of another aquatic invasive plant (water chestnut, *Trapa natans*) to wetlands located at the inflow of the St. Lawrence River, eastern Lake Ontario wetlands could become increasingly affected by aquatic invasive species in the near future. Ongoing efforts such as the CWM program are critical to identifying sites for management and restoration, in addition to providing important information to better understand the potential impacts and provide surveillance of these species.

We have also continued to monitor expansion of the distribution of invasive *Phragmites* in wetlands of southeastern Lake Huron. During the period of successive low water years, many wetlands in this area, up to the Bruce Peninsula, were left stranded (perched) above a rocky shoreline that was exposed by the low water. The bedrock shelves prevented wetland expansion into the lower-elevation rocky substrates. However, *Phragmites* colonized these areas through outgrowth of horizontal rhizomes. This had led to the establishment of *Phragmites* beds at a lower elevation than the wet meadows, and lower even than some of the more hydrophilic marsh plants (e.g., bulrush) now that the water has risen. This could represent a significant new mode of expansion of this aggressively invasive species.

Sites of special interest (benchmark sites)

The number of benchmark sites included in annual surveys varied annually, reflecting our evolving interactions with various collaborators and agencies and their restoration initiatives. Important benchmark sites included:

Crane Creek, in the Ottawa National Wildlife Refuge, OH, as part of an ongoing collaboration with Kurt Kowalski (USGS) who was overseeing a complementary marsh monitoring program. The Crane Creek site continues to be a study area of interest to the USGS, who wished to see how the findings of their GLRI-funded work compared with the results of surveys using the standardized Coastal Wetland Monitoring methodology (K. Kowalski, USGS, Ann Arbor, MI, pers. comm.). We expect to continue our collaboration with the USGS team to compare our among-year estimates of variation with their repeated-sampling-within-year design. This will provide important information on the degree to which a single, synoptic visit represents the community as assessed by repeated sampling over the course of a field season.

Mentor Marsh, OH: The Mentor Marsh site was sampled at the request of a local citizen/scientist in collaboration with the Cleveland Museum of Natural History, the organization responsible for the marsh.

Sturgeon Bay, eastern Georgian Bay, at the request of Environment Canada and Climate Change due to concerns over eutrophication and bluegreen algal blooms.

A restoration site near Stobie Creek in the North Channel of Lake Huron. The Stobie Creek site is targeted for some restoration work, so we collected baseline data for the Kensington Conservancy.

A site on Honey Harbour, Georgian Bay, was sampled to provide information to Environment Canada and other, local interests regarding the invasion of the marsh by invasive *Phragmites*.

Project Leverage Examples

The Canadian Wildlife Service – Ontario Region continues its research on the factors relating to the presence of *Nitellopsis obtusa* in Great Lakes coastal wetlands. The CWS is continuing special efforts to document this species' current distribution and potential impacts on fish and wildlife. In addition, the CWS continues to study the range of natural variability in coastal wetland Indices of Biotic Integrity values. This information will allow agencies to assess the precision of the index and ultimately determine the minimum change in an index score that represents a measurable change in biotic metrics or chemical parameters. This type of information is of special value to resource management agencies and partners who require guidance in interpreting trends in the scores of biotic indices through time, especially the differences observed before and after undertaking restoration projects. The CWM program has allowed CWS staff to collect information at additional sites to supplement its current study.

Bird Studies Canada, in collaboration with all other bird and frog PIs, combined CWM bird and frog data with data from two other broad-scale marsh bird and frog monitoring programs—the Great Lakes Environmental Indicator project (GLEI) and the Great Lakes Marsh Monitoring Program (GLMMP)—to produce the most comprehensive marsh bird and frog dataset to date for coastal and inland Great Lakes wetlands. The project team, led by Bird Studies Canada, then used this first-ever massive dataset to write and successfully submit the Coastal Wetland Birds and Coastal Wetland Amphibians chapters for the upcoming State of the Great Lakes Ecosystem Report. In addition, the project team, again led by Bird Studies Canada, used the large dataset to author and submit for peer review a paper entitled “Influence of broadcast timing and survey duration on marsh breeding bird point count results”. Together these publications, which were enhanced substantially by CWM data, will contribute greatly to Great Lakes wetland conservation.

Collaborations

The Canadian team frequently engaged in discussion and/or site visits, and special efforts were made to develop and foster good stakeholder relationships and to establish collaborations with local groups around the Great Lakes with whom we could interact, explain the purpose and value of the project, and initiate collaborations. Our continuing efforts to coordinate with the environmental liaison individuals for First Nations lands have again met with very limited success. Examples of such collaborations include:

Greg Mayne (Environment Canada, Canadian Co-chair, Lake Huron Binational Partnership) – we designated Honey Harbour a benchmark site at the request of local interests, communicating through Greg. The interest in the site stems from an ongoing invasion of the site by invasive *Phragmites*.

Kurt Kowalski (USGS; work at Crane Creek marsh, Ottawa National Wildlife Reserve) - comparing methods and presumably results of USGS vs. CWM initiatives. We sampled Crane Creek Marsh as a Benchmark site. We will apply both CWM metrics and GLEI-derived indicators of fish and plant condition to both our annual data (collected over 3 consecutive years) with scores calculated from the biweekly sampling program that USGS conducted in 2013. This will allow us to compare among-year to within-year variability both on sampling effectiveness and on the precision of multimetric and multivariate indicator scores calculated from the data.

Kensington Conservancy (Lake Huron's North Channel near Bruce Mines) – we have coordinated with this group over the last four years, mainly for information sharing on sites, but we designated one site, Stobie Creek, a benchmark site at their request.

Linda Sekura, environmental consultant, and Cleveland Museum of Natural History – we designated Mentor Marsh, Ohio, a benchmark site this year. Multiple *Phragmites*-control methods are being implemented at the site. We were asked to collect data, and will sample there in future to track changes to the marsh.

Training Future Scientists

Over the 5-y course of the project, University of Windsor trained and employed 14 undergraduate summer field assistants for one or more seasons each. Eight of these students completed Honours B.Sc. theses as a result of their association with the project. Eleven of these students went on to enroll in M.Sc. or other postgraduate training, 3 in our laboratory.

ASSESSMENT AND OVERSIGHT

The project QAPP was approved and signed on March 21, 2011. The revised QAPP_r5 was signed by all co-PIs on January 23, 2015 and was signed by US EPA on March 25, 2015.

Major QA/QC elements that were carried out include:

- Training of all new laboratory staff responsible for macroinvertebrate sample processing: This training was conducted by experienced technicians at each regional lab and was overseen by the respective co-PI or resident macroinvertebrate expert. Those labs without such an expert sent their new staff to the closest collaborating lab for training (e.g., LSSU sent their invertebrate taxonomist for additional training with NRRI taxonomists). Several members of the Central Basin Team met at Central Michigan University to discuss and come to consensus on invertebrate taxonomy that were particularly challenging for laboratory staff. This meeting has become an annual occurrence and helps to ensure accurate and consistent taxonomy among labs.

- Collection and archiving of all training/certification documents and mid-season QA/QC forms from regional labs: These documents have all been scanned to PDF and will be retained as a permanent record for the project.

- QC checks for all data entered into the data management system (DMS): Every data point that is entered into the DMS was checked to verify consistency between the primary record (e.g., field data sheet) and the database. This is a requirement before data are analyzed or used to calculate IBI metrics.

- Macroinvertebrate QC checks: Each regional lab that processed macroinvertebrate samples has 'blindly' traded samples with the next closest regional lab. Swaps were made between labs that sampled wetlands at a similar latitude to ensure familiarity with the taxa being evaluated. Labs sent two previously-processed samples with relatively high taxa diversity to their assigned QC lab, and then sent the corresponding IDs and counts to the QA managers. Each sample was contained in a single vial that was identified with a unique code that precluded the receiving lab from determining the site or vegetation zone that the sample originated from. The receiving lab then processed the sample as usual and sent the IDs and counts to the QA managers. The QA managers then compared the original IDs with the QC IDs to determine correspondence between the two labs. Inconsistencies in taxa IDs were resolved by a 3rd or 4th lab when necessary or by additional taxonomic experts, depending on the nature of the discrepancy. After QA managers compared original and QC taxa IDs and counts, and resolved discrepancies, they communicated results and necessary corrections to the various labs. In the past two years, the QC swaps have identified very few inconsistencies among regional labs and all inconsistencies have been addressed.

- Mid-season QC checks: Mid-season QC checks were done by all PIs during the field season for each taxonomic group sampling crew. After five years of sampling, most teams have a number of experienced crew members and required little correction during the field season.

- Creation/maintenance of specimen reference collections: Reference collections for macroinvertebrates, fish, and plants are being created or maintained by each regional team.

- Data Quality Objectives (DQO) for laboratory analyses: Participating water quality laboratories have generated estimates of precision, bias, accuracy, representativeness, completeness, comparability, and sensitivity for all water quality analyses. These metrics were archived by each regional laboratory.

- Nutrient detection limits: QC managers discovered that some regional labs were entering data that were below the analytical detection limits established in the QAPP. These higher-precision data reflect the heightened capabilities of some regional labs. Having data from multiple labs with differing detection limits can present problems when analyzing nutrient data that is near detection limits. Therefore, we developed a standard way for labs to enter their data at the precision of their lab's instrumentation. The data management system archives and delivers both these higher-precision data and data at the standard detection limit. In other words, observations falling below the detection limits listed in the QAPP will be “brought up” to the standard level while the original data will still be available for those interested in using it.

Example Water Quality QC Information

Laboratory Quality Assurances:
Water quality analyses from 2015 have been completed by the NRRI Central Analytical Laboratory, Central Michigan University’s Wetland Ecology Laboratory, Grand Valley State University’s Annis Water Resources Institute, and Environment Canada’s National Laboratory for Environmental Testing. Most laboratory results from 2015 have passed the criteria shown below (Table 24) or have been flagged accordingly.

Table 24. Data acceptance criteria for water quality analyses.

QA Component	Acceptance Criteria
External Standards (QCCS)	± 10%
Standard curve	$r^2 \geq 0.99$
Blanks	± 10%
Blank spikes	± 20%
Mid-point check standards	± 10%
Lab Duplicates	± 15% RPD* for samples above the LOQ**
Matrix spikes	± 20%

**Relative Percent Difference (RPD):* While our standard laboratory convention is to analyze 10% of the samples in duplicate and use %RSD (100 * CV) of the duplicates as a guide for accepting or rejecting the data, another measure of the variation of duplicates is RPD: RPD = ((|x1-x2|)/mean) *100.
** LOQ = *Limit of Quantification:* The LOQ is defined as the value for an analyte great enough to produce <15% RSD for its replication. LOQ = 10(S.D.) where 10(S.D.) is 10 times the standard deviation of the gross blank signal and the standard deviation is measured for a set of two replicates (in most cases).

Variability in Field Replicates:
An analysis of field duplicate variability for the project years is shown in Table 25. It is important to note that, for many constituents, the variability within sample sets is related to the mean concentration, and as concentrations approach the method detection limit (MDL), the variability increases dramatically. A calculation of field replicate variability with values at or near the level of detection will often result in high RPDs. For example, if the chlorophyll measurements on a set of field duplicates are 0.8 µg/L and 0.3 µg/L, mean = 0.6, resulting in a

RPD of 91% (RPD = [abs (rep a-rep b)/ (rep a+ rep b)/2)]*100, but since the MDL is ± 0.5 µg/L, this can be misleading.

The same can occur with analyte lab duplicates. It is also important to note that RPD on field duplicates incorporates environmental (e.g., spatial) variability, since duplicate samples were collected from adjacent locations, as well as analytical variability (e.g., instrument drift). Therefore, RPD of field duplicates was generally higher than RPD of laboratory duplicates. Table 25 below lists average RPD values for each year of the project (2011-2015). Higher than expected average RPD values were associated with a preponderance of near-detection-limit values for ammonium, nitrate, and soluble reactive phosphorus (SRP), and high spatial variability for chlorophyll and turbidity. Other variables, such Total N, had values that were well above detection limit and low spatial variability; therefore, these values had much lower average RPD. The maximum expected RPD values were based on the MN Pollution Control Agency quality assurance project plan provided for the Event Based Sampling Program (http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/surface-water-financial-assistance/event-based-sampling-grants.html#for-grantees).

Table 25. Water quality method detection limits (MDL), maximum expected and observed relative percent differences (RPD) for field duplicates per sampling year. Average RPD, (n), and RPD ranges are included for each year. Data are from all analytical laboratories combined.

Analyte	**MDL**	**Maximum expected RPD**	**2011**	**2012**	**2013**	**2014**	**2015**
Chlorophyll-a	--	30	45 (15) 0-99	36 (13) 5-106	46 (15) 16-124	36 (21) 0-97	45 (8) 18-88
Total P	0.002 mg/L NRRI, C-NLET 0.005 mg/L CMU	30	20 (13) 0-82	27 (13) 0.5-100	28 (17) 5-124	32 (19) 0-164	17 (9) 1-47
SRP	0.002 mg/L	10	18 (16) 0-67	16 (12) 0-80	16 (17) 0-67	44 (20) 0-200	49 (9) 4-190
Total N	0.010 mg/L	30	10 (13) 0-34	10 (13) 0-27	7 (17) 0.4-22	21 (19) 0-94	15 (8) 2-32
NH4-N	0.01 mg/L	10	48 (16) 0-137	22 (13) 0-123	24 (17) 4-200	52 (20) 0-200	24 (9) 0-100
NO2/NO3-N	0.004 mg/L	10	43 (16) 0-200	20 (13) 0-54	24 (17) 0-80	13 (20) 0-80	11 (9) 0-32
True color	--	10	12 (14) 0-43	5 (11) 0-21	3 (12) 1-8	13 (16) 0-40	7 (10) 0-21
Chloride	0.01 mg/L	20	2 (12) 0-9	14 (11) 0.4-89	13 (13) 0-67	17 (20) 0-63	6 (10) 0.3-23

In addition to tracking RPDs through time, QA managers assessed RPDs per laboratory to identify any potential analytical performance issues (Table 26). Again, the average RPDs that exceeded the maximum expected RPD were associated with a large number of values that were at or near method detection limits. Therefore, no laboratory specific or project-wide corrective actions were deemed necessary.

Table 26. Water quality method detection limits (MDL), maximum expected and observed relative percent differences (RPD) for field duplicates per laboratory. Average RPD, (n), and RPD ranges are included for each laboratory. Data are from 2011-2015 sampling seasons.

Analyte	**MDL**	**Maximum expected RPD**	**All Labs**	**CMU**	**C-NLET**	**NRRI**	**UND**
Chlorophyll-a	--	30	na	na	na	45 (29) 5.4-97	42 (44) 0-124
Total P	0.002 mg/L NRRI, C-NLET 0.005 mg/L CMU	30	26(71) 0-164	32 (20) 0-100	20(22) 0-164	26(29) 2-124	na
SRP	0.002 mg/L	10	28(73) 0-200	29(23) 0-200	46(21) 0-190	13(29) 0-50	na
Total N	0.010 mg/L	30	13(70) 0-94	12(20) 0-43	7(22) 0-20	18(28) 0-94	na
NH4-N	0.01 mg/L	10	45(75) 0-200	41(24) 0-200	39(22) 0-191	52(29) 0-200	na
NO2/NO3-N	0.004 mg/L	10	20(74) 0-200	32(24) 0-198	10(22) 0-87	19(28) 0-200	na
True color	--	10	8(63) 0-43	14(13) 0-43	7(22) 0-40	7(28) 0-36	na
Chloride	0.01 mg/L	20	11.3(66) 0-88.9	16.5(16) 0-66.7	9.9(22) 0-63.5	9.4(28) 0-88.9	na

Communication among Personnel

Regional team leaders and co-PIs maintained close communication during the whole five years of the project. The lead PI, all co-PIs, and many technicians attended an organizational meeting in Michigan during the winter of each project year. Project officer Dr. Kevin O'Donnell (EPA) attended most of these meetings, which also occasionally included others interested in collaborations or spin-off projects.

Regional team leaders and co-PIs have held conference calls and e-mail discussions regarding site selection and field work preparation throughout the duration of the project. Most PIs spent the first week of field season in the field with their crew to ensure that all protocols were being followed according to the standards set forth in the QAPP and SOPs and to certify or re-certify crew members. PIs kept in close contact with field crews via cell phone, text, and email, and the leadership team was also always available via cell phone and text to answer the most difficult crew questions.

Overall

No major injuries were reported by any field crew members during any of the five years of the project, which speaks to the safety consciousness and diligence of our field crew chiefs. This safety record is even more impressive considering the number of crew members in the field all summer long and the weather conditions and remote locations in which they worked. PIs were continually impressed by the work ethics of their field crews, their willingness to work long hours day after day, to successfully sample under quite adverse conditions, and to conduct sampling in accordance with strict QA procedures.

The quality management system developed for this project has been fully implemented and co-PIs and their respective staff members followed established protocols very closely, relying on the QAPP and SOPs as guiding documents. QA managers were also encouraged by each crew's continued willingness to contact their supervisors or, in many cases, the project management team when questions arose.

LEVERAGED BENEFITS OF PROJECT (2010 – 2015)

This project has generated a number of spin-off projects and served as a platform for many graduate and undergraduate thesis topics. In addition, project PIs collaborated with many other groups to assist them in getting data for areas that are or will be restored or that are under consideration for protection. Finally, the project supported or partially supported many jobs (jobs created/retained). All of these are detailed below.

Spin-off Projects (cumulative since 2010)

Conservation Assessment for Amphibians and Birds of the Great Lakes: To examine the role of Great Lakes wetlands in the conservation of birds in North America, an effort has been initiated to assess the importance of these coastal wetlands as migratory or breeding grounds. A similar effort will also be initiated for amphibians, because many of the amphibians (and birds) living in these coastal wetlands have been identified as endangered (e.g. Northern Cricket Frog), threatened, or of special concern (e.g., Sedge Wren, Northern Leopard Frog) in multiple states.

A recent study, targeting Sedge and Marsh Wren distributions within the Great Lakes coastal wetlands, modeled habitat and landscape characteristics against presence/absence of each species at multiple spatial scales. This analysis will determine how these characteristics influence the distribution and abundance of species breeding habitat. Classification trees were used to predict both Sedge and Marsh Wren presence and relative high abundance (≥3 wrens/site). The best classification trees (i.e., those with the lowest classification error) predict Sedge Wrens to be present in wetlands with >9% woody vegetation, and in high abundance in wetlands with <3% cattails and >4% meadow vegetation. Marsh Wrens were positively associated with emergent vegetation and cropland, and in high abundance in wetlands with >14% cattails. Probability maps were created based on best fitting models to help predict breeding habitat. These results suggest which characteristics of the Great Lakes coastal wetlands are important to these two wetland-obligate bird species, and can be useful to inform management plans for these species. These models can also be developed for other obligate wetland species within the Great Lakes wetlands.

The extensive data that have been gathered by US EPA such as the Great Lakes Environmental Indicators project and the Great Lakes Wetlands Consortium as well as Bird Studies Canada will provide critical input to this assessment. The proposed large-scale modeling effort will be one of the broadest analyses in terms of sample size and geographic area. It will also serve as a valuable tool for future management decisions relating to Great Lakes wetland conservation.

North Maumee Bay Survey of Diked Wetland vs. Un-Diked Wetland: Erie Marsh Preserve was studied as a benchmark site for the CWM project. As a benchmark site, Erie Marsh Preserve served as a comparison against randomly-selected project sites, and was surveyed each year of the CWM project. Benchmark sampling began prior to Phase 1 of a planned restoration by The Nature Conservancy, allowing for pre- and post-restoration comparisons. In addition, biota and habitat within the diked wetlands area will be compared to conditions outside of the dike, but still within the preserve. These data will also be used for post-construction comparisons to determine what biotic and abiotic changes will occur once restoration efforts have reconnected the dike to the shallow waters of Lake Erie.

Cattails-to-Methane Biofuels Research: CWM crews collected samples of invasive plants (hybrid cattail) which are being analyzed by Kettering University and their Swedish Biogas partner to determine the amount of methane that can be generated from this invasive. These samples will be compared to their dataset of agricultural crops, sewage sludge, and livestock waste that are currently used to commercially generate methane. The cattails-to-methane biofuels project is also funded (separately) by GLRI.

Plant IBI Evaluation: A presentation at the 2014 Joint Aquatic Science meeting in Portland, Oregon evaluated Floristic Quality Index and Mean Conservatism score changes over time using data collected during the first three years of the CWM project. Mean C scores showed little change between years from 2011 through 2013 due to stable water levels.

Correlation between Wetland Macrophytes and Wetland Soil Nutrients: CWM vegetation crews collected wetland soil samples and provided corresponding macrophyte data to substantially increase the number of sites and samples available to the USEPA Mid-Continent Ecology Division. USEPA MED researchers studied wetland macrophyte and wetland soil nutrient correlations. The MED laboratory ran the sediment nutrient analyses and shared the data with CWM PIs.

Comparative study of bulrush growth between Great Lakes coastal wetlands and Pacific Northwest estuaries. This study includes investigation of water level effects on bulrush growth rates in Great Lakes coastal wetlands using leveraged funding from NSF for the primary project on bulrush ability to withstand wave energy.

Braddock Bay, Lake Ontario, Sedge Meadow and Barrier Beach Restoration: Braddock Bay was studied as a benchmark site in conjunction with the US Army Corps of Engineers to assess the current extent of, and potential restoration of, sedge meadow and the potential of restoring the eroded barrier beach to reduce wetland loss. CWM crews collected pre-restoration data to help plan and implement restoration activities and will collect post-restoration data to help plan and implement restoration activities and assess results. The results will help build a model for future sedge meadow restoration in Lake Ontario to mitigate the harmful impacts of invasive cattails and provide habitat for fish and wildlife species. Additionally, this project will be expanded, in conjunction with Ducks Unlimited, to four nearby wetlands, pending funding from NOAA.

Thunder Bay AOC, Lake Superior, Wetland Restoration: Nine wetlands around Thunder Bay were sampled for macroinvertebrates, water quality, and aquatic vegetation by CWM crews in 2013 using methods closely related to CWM methods. These data will provide pre-restoration baseline data as part of the AOC delisting process. Wetlands sampled included both wetlands in need of restoration and wetlands being used as a regional reference. All of this sampling was in addition to normal CWM sampling, and was done with funding from Environment Canada.

Common Tern Geolocator Project: In early June 2013, the NRRI CWM bird team volunteered to assist the Wisconsin DNR in deploying geolocator units on Common Terns nesting on Interstate Island. In 2013, 15 birds between the ages of 4-9 yrs old were outfitted with geolocators. Body measurements and blood samples were also taken to determine the sex of each individual. In June of 2014, geolocators were removed from seven birds that returned to nest on the island. Of the seven retrieved geolocators, four were from female birds and three from males. The data collected during the year will be used to better understand the migratory routes of Common Terns nesting on Interstate Island. This is the first time that geolocators have been placed on Common Terns nesting in the Midwest, which is important because this species is listed as threatened in Minnesota and endangered in Wisconsin. Tracking Common Terns throughout their annual cycle will help identify locations that are important during the non-breeding portion of their life cycle. Data are currently being analyzed by researchers at the Natural Resources Research Institute in Duluth MN.

Developing a Decision Support Tool for Prioritizing Protection and Restoration of Great Lakes Coastal Wetlands: While a number of large coastal wetland restoration projects have been initiated in the Great Lakes, there remains little regional or basin-scale prioritization of restoration efforts. Until recently we lacked the data necessary for making systematic prioritization decisions for wetland protection and restoration. However, now that basin-wide coastal wetland monitoring data is available, development of a robust prioritization tool is possible and we have developed a new Decision Support Tool (DST) to prioritize protection and restoration investments. This project, funded by the Upper Midwest and Great Lakes Landscape Conservation Cooperative, developed a DSS for wetlands from Saginaw Bay to Western Lake Erie and is now being expanded to other areas of the Great Lakes.

Quantifying Coastal Wetland – Nearshore Linkages in Lake Michigan for Sustaining Sport Fishes: With support from Sea Grant (Illinois-Indiana and Wisconsin programs), personnel from UND and CWM are comparing food webs from coastal wetlands and nearshore areas of Lake Michigan to determine the importance of coastal wetlands in sustaining the Lake Michigan food web. The project emphasis is on identifying sport fish-mediated linkages between wetland and nearshore habitats. Specifically, we are (1) constructing cross-habitat food webs using stable C and N isotope mixing models, (2) estimating coastal wetland habitat use by sport fishes using otolith microchemistry, and (3) building predictive models of both linkage types that account for the major drivers of fish-mediated linkages in multiple Lake Michigan wetland types, including some wetlands sampled by the coastal wetland monitoring project. Collaborators are the University of Wisconsin – Green Bay and Loyola University Chicago.

Clough Island (Duluth/Superior) Preservation and Restoration: The Wisconsin Department of Natural Resources requested (and funded) a special report on sites sampled using CWM protocols around Clough Island within the St. Louis River Area of Concern (AOC). Their interests were to see if CWM data indicated any differences in habitat or species composition/abundances among Clough Island and other St. Louis River sites, and also how Clough Island compared to other nearby Lake Superior coastal wetlands. The 46 page report was submitted to Cherie Hagan of the WDNR in May of 2014. Clough Island was recently acquired by the Nature Conservancy and they are using the data in the report for their development of conservation plans for the area.

Floodwood Pond and Buck Pond South, Lake Ontario, Wetland Pothole Restoration: Open water potholes were established in these two wetlands by The Nature Conservancy to replace openings that had filled with cattail following lake-level regulation. CWM crews collected pre- and post-restoration data as benchmark sites in both wetlands to allow TNC to assess changes.

Buck Pond West and Buttonwood Creek, Lake Ontario, Sedge Meadow Restoration: These two wetlands in the Rochester Embayment AOC are actively being restored by a consortium involving Ducks Unlimited, The College at Brockport, NYS Department of Environmental

Conservation, and the Town of Greece. CWM crews collected pre-restoration data as a benchmark site to help plan and implement restoration activities. Post-restoration data collection was also collected by CWM crews to help assess results and help build a model for future sedge meadow restoration in Lake Ontario to mitigate the harmful impacts of invasive cattails and provide habitat for fish and wildlife species.

Salmon/West Creek, Long Pond, and Buck Pond East, Lake Ontario, Emergent Marsh Restoration: These three wetlands in the Rochester Embayment AOC were studied as benchmark sites by CWM crews to provide the U.S. Fish and Wildlife Service with pre-restoration data for projects currently in the design phase. Future CWM data collection has been requested to assist in post-restoration assessment.

Lower Green Bay and Fox River AOC: Results from the Coastal Wetland Monitoring (CWM) Project and the Great Lakes Environmental Indicators (GLEI) Project are playing a central role in a $471,000 effort to establish de-listing targets for the Lower Green Bay and Fox River AOC. 1) Protocols for intensive sampling of birds and amphibians in the project area have followed the exact methods used in the CWM project so that results will be directly comparable with sites elsewhere in the Great Lakes. 2) Data from GLEI on diatoms, plants, invertebrates, fish, birds, and amphibians and from CWM on birds and amphibians have been used to identify sensitive species that are known to occur in the AOC and have shown to be sensitive to environmental stressors elsewhere in the Great Lakes. These species have been compiled into a database of priority conservation targets. 3) Methods of quantifying environmental condition developed and refined in the GLEI and CWM projects are being used to assess current condition of the AOC (as well as specific sites within the AOC) and to set specific targets for de-listing of two important beneficial use impairments (fish and wildlife populations and fish and wildlife habitats).

SOLEC Indicators: The bird and amphibian team developed a draft set of indicator metrics submitted to the State of the Lake Indicator Conference (SOLEC) in October 2015. These metrics will fill a much-needed gap in quantifying responses of bird and amphibian communities to environmental stress throughout the Great Lakes. Sites for all coastal wetlands sampled by the GLEI, CWM, and Marsh Monitoring projects have been scored according to several complementary indices that provide information about local and regional condition of existing wetlands.

Roxana Marsh Restoration (Lake Michigan): The University of Notre Dame (UND) team, led by graduate student Katherine O'Reilly and undergraduate Amelia McReynolds under the direction of project co-PI Gary Lamberti, leveraged the CWM monitoring project to do an assessment of recently-restored Roxana Marsh along the south shore of Lake Michigan. Roxana Marsh is a 10-ha coastal wetland located along the Grand Calumet River in northwestern Indiana. An EPA-led cleanup of the west branch of the Grand Calumet River AOC including the marsh was completed in 2012 and involved removing approximately 235,000 cubic yards of contaminated sediment and the reestablishment of native plants. Ms. McReynolds obtained a summer 2015 fellowship from the College of Science at UND to study the biological recovery of Roxana Marsh, during which several protocols from the GLCWM project were employed.

During summer 2015 sampling of Roxana Marsh, an unexpected inhabitant of the Roxana Marsh was discovered -- the invasive oriental weatherfish (*Misgurnus anguillicaudatus*). Oriental weatherfish are native to southeast Asia and are believed to have been introduced to the U.S. via the aquarium trade. Although there have been previous observations of *M. anguillicaudatus* in the river dating back to 2002, it had not been previously recorded in Roxana Marsh, and little information is available on its biological impacts there or elsewhere. We are currently using stable carbon and nitrogen isotopes, along with diet analysis, to determine the role of *M. anguillicaudatus* in the wetland food web and its potential for competition with native fauna for food or habitat resources.

Green Bay Area Wetlands: Data from the benchmark site Suamico River Area Wetland was requested by and shared with personnel from the Wisconsin Department of Natural Resources and The Nature Conservancy, who are involved in the restoration activities to re-connect a diked area with Green Bay. In 2011 NRRI sampled outside the diked area following CWM methods, and in 2013 we sampled within the diked area as a special request. The data were summarized for fish, invertebrates, water quality, birds, and vegetation and shared with David Halfmann (WDNR) and Nicole Van Helden (TNC).

Hybridizing fish: One interesting phenomenon around the Green Bay area of Lake Michigan is the regular occurrence of gar that are likely hybrids between shortnose and longnose species. The Wisconsin Department of Natural Resources recently documented a number of hybrid individuals in the Fox River watershed, but not within Green Bay proper. In 2013 the NRRI field crew encountered gar exhibiting mixed traits which suggested hybridization, and in 2014 we developed a plan project-wide to collect fin-clip tissue samples to genetically test for hybridization. NRRI collected 22 tissue samples that await DNA analysis, and we will continue to collect fin clips from gar encountered in 2015.

Support for Un-affiliated Projects

CWM PIs and data managers continue to provide data and support to other research projects around the Great Lakes even though CWM PIs are not collaborators on these projects. Dr. Laura Bourgeau-Chavez at Michigan Tech University had a project to map the spatial extent of Great Lakes coastal wetlands using GIS and satellite information to help in tracking wetland gains and losses over time (Implementation of the Great Lakes Coastal Wetlands Consortium Mapping Protocol, funded by GLRI). CWM provided her with vegetation data and sampling locations each year to assist with this effort. Dr. Bourgeau-Chavez also received funding to assess herbicide effectiveness against *Phragmites* in Green Bay and Saginaw Bay. CWM data were used to find the best locations, provide baseline data, and provide pointers on site access (from field crew notes) in support of this project.

Reports on new locations of non-native and invasive species: Vegetation sampling crews and PIs have been pro-active over the years in reporting new locations of invasive vegetation. Fish and macroinvertebrate PIs and crews belatedly realized that they may be discovering new locations of invasive species, particularly invasive macroinvertebrates. To ensure that all new sightings get recorded, we began routinely pulling all records of non-native fish and macroinvertebrates out of the database once per year and sending these records to the Nonindigenous Aquatic Species tracking website maintained by USGS (http://nas2.er.usgs.gov/). Wetland vegetation PIs contributed new SOLEC indicator guidelines and reports and continue to participate in the indicator review process Fall 2015 and Spring 2016.

Wetland Floristic Quality in the St. Louis River Estuary: With support from WI Sea Grant 2016-2017, vegetation PI N. Danz integrated vegetation surveys from the CWM project with data from 14 other recent projects in the estuary. A new relational database was created that is being used to assess spatial and temporal patterns in floristic quality and to develop materials to inform and monitor wetland restorations in this AOC.

Requests for Assistance Collecting Monitoring Data

Project PIs provided monitoring data and interpretation of data for many wetlands where restoration activities were being proposed by applicants for “Sustain Our Great Lakes” funding. This program is administered by the National Fish and Wildlife Foundation (NFWF) and includes GLRI funding. Proposal writers made data/information requests via NFWF, who communicated the requests to us. Lead PI Don Uzarski, with assistance from co-PIs, then pulled relevant project data and provided interpretations of IBI scores and water quality data. This information was then communicated to NFWF, who communicated with the applicants. This information sharing reflects the value of having coastal wetland monitoring data to inform restoration and protection decisions. We anticipate similar information sharing in the coming years as additional restoration and protection opportunities arise.

In addition to the NFWF program, CWM PIs received many requests to sample particular wetlands of interest to various agencies and groups. In some instances the wetlands were scheduled for restoration and the CWM project provided pre-restoration data. Some requests also were for post-restoration sampling in hopes of showing the beginnings of site condition improvement. Such requests have come from the St. Louis River (Lake Superior), Maumee Bay (Lake Erie), and Rochester (Lake Ontario) Area of Concern delisting groups, as well as the Great Lakes National Park Service and the Nature Conservancy (sites across lakes Michigan and Huron for both groups). Several requests involve restorations specifically targeted to create habitat for biota that are being sampled by CWM. Examples include: a NOAA-led restoration of wetlands bordering the Little Rapids of the St. Marys River to restore critical spawning habitat for many native freshwater fishes and provide important nursery and rearing habitat in backwater areas; TNC-led restoration of pike spawning habitats on Lake Ontario and in Green Bay; a US Army Corps of Engineers project in Green Bay to create protective barrier islands and restore many acres of aquatic and wetland vegetation; a USACE project to improve wetland fish and vegetation habitat in Braddock Bay, Lake Ontario, and a New York state project to increase nesting habitat for state-endangered black tern. Many of these restoration activities are being funded through GLRI, so through collaboration we increased the efficiency and effectiveness of restoration efforts across the Great Lakes basin.

At some sites, restoration was still in the planning stages and restoration committees were interested in the CWM data to help them create a restoration plan. This happened in the St. Louis River AOC, in Sodus Bay, Lake Ontario, for the Rochester NY AOC, and for the St. Marys River restoration in 2015 by tribal biologists at Sault Ste Marie.

Other groups requested help sampling sites that are believed to be in very good condition (at least for their geographic location), or are among the last examples of their kind, and are on lists to be protected. These requests came from The Nature Conservancy for Green Bay sites (they are developing a regional conservation strategy and attempting to protect the best remaining sites); the St. Louis River AOC delisting committee to provide target data for restoration work (i.e., what should a restored site “look” like); and the Wisconsin DNR Natural Heritage Inventory requested assistance in looking for rare, endangered, and threatened species and habitats in all of the coastal wetlands along Wisconsin’s Lake Superior coastline. Southern Lake Michigan wetlands have mostly been lost, and only three remain that are truly coastal wetlands. CWM PIs worked with Illinois agencies and conservation groups to collaboratively and thoroughly sample one of these sites, and the results will be used to help manage all 3 sites.

Other managers have also requested data to help them better manage wetland areas. For example, the Michigan Clean Water Corps requested CWM data to better understand and manage Stony Lake, Michigan. Staff of a coal-fired power plant abutting a CWM site requested our fish data to help them better understand and manage the effects of their outfalls on the resident fish community. The Michigan Natural Features Inventory requested our data as part of a GLRI-funded invasive species mapping project. The US Fish and Wildlife Service requested all data possible from wetlands located within the Rochester, NY, Area of Concern as they assess trends in the wetlands and compare data to designated delisting criteria. The NERR on Lake Erie (Old Woman Creek) has requested our monitoring data to add to their own. The University of Wisconsin Green Bay will use our data to monitor control of *Phragmites* in one of their wetlands, and hope to show habitat restoration. Thunder Bay National Marine Sanctuary (Lake Huron) has requested our data to facilitate protection and management of coastal resources within the Sanctuary. The Wisconsin DNR has requested data for the Fish Creak

Wetland as part of an Environmental Impact Assessment related to a proposed Confined Animal Feeding Operation upstream of the wetland.

We received a request from the USFWS for data to support development of a black tern distribution/habitat model for the Great Lakes region. The initial effort focused on Lakes Huron, Erie and their connecting channels. Various FWS programs (e.g., Migratory Bird, Joint Venture, and Landscape Conservation Cooperatives) are interested in this model as an input to conservation planning for Great Lakes wetlands.

The College at Brockport notified an invasive species rapid-response team led by The Nature Conservancy after each new sighting of water chestnut. Coupling the monitoring efforts of this project with a rapid-response team helped to eradicate small infestations of this new invasive before it became a more established infestation.

We also received requests to do methods comparison studies. For example, USGS and Five Fathom National Marine Park both requested data and sampling to compare with their own sampling data.

Overall, CWM PIs had many requests to sample specific wetlands. It was challenging to accommodate all requests within our statistical sampling design and our sampling capacities.

Student Research Support

Graduate Research with Leveraged Funding:

- Importance of coastal wetlands to offshore fishes of the Great Lakes: Dietary support and habitat utilization (Central Michigan University; with additional funding from several small University grants and the US Fish and Wildlife Service).
- Spatial variation in macroinvertebrate communities within two emergent plant zones in Great Lakes coastal wetlands (Central Michigan University; with additional funding from CMU).
- Invertebrate co-occurrence patterns in coastal wetlands of the Great Lakes: Community assembly rules (Central Michigan University; additional funding from CMU)
- Functional indicators of Great Lakes coastal wetland health (University of Notre Dame; additional funding by Illinois-Indiana Sea Grant).
- Evaluating environmental DNA detection alongside standard fish sampling in Great Lakes coastal wetland monitoring (University of Notre Dame; additional funding by Illinois-Indiana Sea Grant).
- Nutrient-limitation in Great Lakes coastal wetlands (University of Notre Dame; additional funding by the UND College of Science).

- A summary of snapping turtle (*Chelydra serpentina*) by-catch records in Lake Ontario coastal wetlands (with additional funding by University of Toronto).
- Evaluating a zoobenthic indicator of Great Lakes wetland condition (with additional funding from University of Windsor).
- Testing and comparing the diagnostic value of three fish community indicators of Great Lakes wetland condition (with additional funding from GLRI GLIC: GLEI II and University of Windsor).
- Quantifying Aquatic Invasion Patterns Through Space and Time: A Relational Analysis of the Laurentian Great Lakes (University of Minnesota Duluth; with additional funding and data from USEPA)
- Novel Diagnostics for Biotransport of Aquatic Environmental Contaminants (University of Notre Dame, with additional funding from Advanced Diagnostics & Therapeutics program)

Undergraduate Research with Leveraged Funding:

- Production of a short documentary film on Great Lakes coastal wetlands (University of Notre Dame; additional funding by the UND College of Arts and Letters).
- Heavy metal and organic toxicant loads in freshwater turtle species inhabiting coastal wetlands of Lake Michigan (University of Notre Dame; additional funding by the UND College of Science).
- *Phragmites australis* effects on coastal wetland nearshore fish communities of the Great Lakes basin (University of Windsor; with additional funding from GLRI GLIC: GLEI II).
- Sonar-derived estimates of macrophyte density and biomass in Great Lakes coastal wetlands (University of Windsor; with additional funding from GLRI GLIC: GLEI II).
- Effects of disturbance frequency on the structure of coastal wetland macroinvertebrate communities (Lake Superior State University; with additional funding from LSSU's Undergraduate Research Committee).
- Resistance and resilience of macroinvertebrate communities in disturbed and undisturbed coastal wetlands (Lake Superior State University; with additional funding from LSSU's Undergraduate Research Committee).
- Structure and function of restored Roxana Marsh in southern Lake Michigan (University of Notre Dame, with additional funding from the UND College of Science)
- Nutrient limitation in Great Lakes coastal wetlands (Central Michigan University, CMU Biological Station on Beaver Island)
- Effects of wetland size and adjacent land use on taxonomic richness (University of Minnesota Duluth, with additional funding from UMD's UROP program)

Graduate Research without Leveraged Funding:

- Impacts of drainage outlets on Great Lakes coastal wetlands (Central Michigan University).
- Effects of anthropogenic disturbance affecting coastal wetland vegetation (Central Michigan University).
- Great Lakes coastal wetland seed banks: what drives compositional change? (Central Michigan University).
- Spatial scale variation in patterns and mechanisms driving fish diversity in Great Lakes coastal wetlands (Central Michigan University).
- Building a model of macroinvertebrate functional feeding group community through zone succession: Does the River Continuum Concept apply to Great Lakes coastal wetlands? (Central Michigan University).
- Chemical and physical habitat variation within Great Lakes coastal wetlands; the importance of hydrology and dominant plant zonation (Central Michigan University)
- Macroinvertebrate-based Index of Biotic Integrity for Great Lakes coastal wetlands (Central Michigan University)
- Habitat conditions and invertebrate communities of Great Lakes coastal habitats dominated by Wet Meadow, and *Phragmites australis*: implications of macrophyte structure changes (Central Michigan University)
- The establishment of *Bithynia tentaculata* in coastal wetlands of the Great Lakes (Central Michigan University)
- Environmental covariates as predictors of anuran distribution in Great Lakes coastal wetlands (Central Michigan University)
- Impacts of muskrat herbivory in Great Lakes coastal wetlands (Central Michigan University).
- Mute swan interactions with native waterfowl in Great Lakes coastal wetlands (Central Michigan University).
- Effects of turbidity regimes on fish and macroinvertebrate community structure in coastal wetlands (Lake Superior State University and Oakland University).
- Scale dependence of dispersal limitation and environmental species sorting in Great Lakes wetland invertebrate meta-communities (University of Notre Dame).
- Spatial and temporal trends in invertebrate communities of Great Lakes coastal wetlands, with emphasis on Saginaw Bay of Lake Huron (University of Notre Dame).
- Model building and a comparison of the factors influencing sedge and marsh wren populations in Great Lakes coastal wetlands (University of Minnesota Duluth).
- The effect of urbanization on the stopover ecology of Neotropical migrant songbirds on the western shore of Lake Michigan (University of Minnesota Duluth).

- Assessing the role of nutrients and watershed features in cattail invasion (*Typha angustifolia* and *Typha* x *glauca*) in Lake Ontario wetlands (The College at Brockport).
- Developing captive breeding methods for bowfin (*Amia calva*) (The College at Brockport).
- Water chestnut (*Trap natans*) growth and management in Lake Ontario coastal wetlands (The College at Brockport).
- Functional diversity and temporal variation of migratory land bird assemblages in lower Green Bay (University of Wisconsin Green Bay).
- Effects of invasive *Phragmites* on stopover habitat for migratory shorebirds in lower Green Bay, Lake Michigan (University of Wisconsin Green Bay).
- Plant species associations and assemblages for the whole Great Lakes, developed through unconstrained ordination analyses (Oregon State University).
- Genetic barcoding to identify black and brown bullheads (Grand Valley State University).
- Coastal wetland – nearshore linkages in Lake Michigan for sustaining sport fishes (University of Notre Dame)
- Anthropogenic disturbance effects on bird and amphibian communities in Lake Ontario coastal wetlands (The College at Brockport)
- A fish-based index of biotic integrity for Lake Ontario coastal wetlands (The College at Brockport)
- Modeling potential nutria habitat in Great Lakes coastal wetlands (Central Michigan University)
- Modeling of Eurasian ruffe (*Gymnocephalus cernua*) habitat preferences to predict future invasions (University of Minnesota Duluth in collaboration with USEPA MED)

Graduate Student Theses

Lisa Elliott. 2018. Modeling species-specific habitat associations of Great Lakes coastal wetland birds. Ph.D. Conservation Biology Graduate Program, University of Minnesota, St. Paul. (in progress)

Jessica Chatterton. 2018. Historical and current use of Great Lakes coastal regions by breeding birds. MS Thesis, Integrated Biological Sciences, University of Minnesota, Duluth. (in progress)

Jon Podoliak. 2017. Anthropogenic disturbance effects on bird and amphibians in Great Lakes coastal wetlands. , Department of Environmental Science and Biology, College at Brockport, SUNY, Brockport, NY. (In progress)

Dylan Hilts. 2016. Current and potential distribution of invasive nutria (Myocastor coypus) in the United States. MS Thesis, Department of Biology, Central Michigan University. (in progress)

Bridget Wheelock. 2016. Environmental covariates as predictors of anuran distribution in Great Lakes coastal wetlands. MS Thesis, Department of Biology, Central Michigan University. (in progress)

Christina Hoh. 2016. Spring stopover ecology and physiology of the White-throated Sparrow (*Zonotrochia albicollis*) in western New York. MS Thesis, Department of Environmental Science and Biology, College at Brockport, SUNY, Brockport, NY. (Completed)

Lizzie Condon. 2015. Habitat use by spring migrating birds on the western coast of Lake Michigan. MS Thesis, Integrated Biological Sciences, University of Minnesota, Duluth. (Completed)

Matthew Cooper. 2015. Structure and function of Great Lakes coastal wetlands. PhD Dissertation, Department of Biology, University of Notre Dame. (Completed)

John Bateman. 2014. Effects of stormwater ponds on calling amphibian communities in Monroe County, New York. MS Thesis, Department of Environmental Science and Biology, College at Brockport, SUNY, Brockport, NY. (Completed)

Hannah Panci. 2013. Habitat and landscape use by marsh and sedge wrens in Great Lakes coastal wetlands. MS Thesis, Integrated Biological Sciences, University of Minnesota, Duluth. (Completed)

Annie Bracey. 2011. Window related avian mortality at a migration corridor. MS Thesis, Integrated Biological Sciences, University of Minnesota, Duluth. (Completed)

Undergraduate Research without Leveraged Funding:

- Sensitivity of fish community metrics to net set locations: a comparison between Coastal Wetland Monitoring and GLEI methods (University of Minnesota Duluth).

- Larval fish usage and assemblage composition between different wetland types (Central Michigan University).

- Determining wetland health for selected Great Lakes Coastal Wetlands and incorporating management recommendations (Central Michigan University).

- Invertebrate co-occurrence trends in the wetlands of the Upper Peninsula and Western Michigan and the role of habitat disturbance levels (Central Michigan University).

- Is macroinvertebrate richness and community composition determined by habitat complexity or variation in complexity? (University of Windsor, complete).

- Modeling American coot habitat relative to faucet snail invasion potential (Central Michigan University)

Jobs Created/Retained (per year, except grad students):

- Principal Investigators (partial support): 14
- Post-doctoral researchers (partial support): 1 (0.25 FTE)
- Total graduate students supported on project (summer and/or part-time): 40 + 1[OSU]
- Paid undergraduate internship (summer): 1[OSU]
- Undergraduate students (summer and/or part-time): 53
- Technicians (summer and/or partial support): 25 (~12 FTE)
- Volunteers: 23

Total jobs at least partially supported per year: 122 (plus 23 volunteers trained).

Presentations about the Coastal Wetland Monitoring Project (inception through 2015)

Albert, Dennis. 2013. Use of Great Lakes Coastal Wetland Monitoring data in restoration projects in the Great Lakes region. 5th Annual Conference on Ecosystem Restoration, Schaumburg, IL. July 30, 2013. 20 attendees, mostly managers and agency personnel.

Albert, Dennis. 2013. Data collection and use of Great Lakes Coastal Wetland Monitoring data by Great Lakes restorationists. Midwestern State Wetland Managers Meeting, Kellogg Biological Station, Gull Lake, MI, October 31, 2013. 40 attendees; Great Lakes state wetland managers.

Albert, Dennis, N. Danz, D. Wilcox, and J. Gathman. 2014. Evaluating Temporal Variability of Floristic Quality Indices in Laurentian Great Lakes Coastal Wetlands. Society of Wetland Scientists, Portland, OR. June.

Albert, Dennis, et al. 2015. Restoration of wetlands through the harvest of invasive plants, including hybrid cattail and *Phragmites australis*. Presented to Midwestern and Canadian biologists. June.

Albert, Dennis, et al. 2015. Great-Lakes wide distribution of bulrushes and invasive species. Coastal and Estuarine Research Federation Conference in Portland, Oregon. November.

Bozimowski, A.A., B.A. Murry, and D.G. Uzarski. Invertebrate co-occurrence patterns in the wetlands of northern and eastern Lake Michigan: the interaction of the harsh-benign hypothesis and community assembly rules. 55th International Conference on Great Lakes Research, Cornwall, Ontario.

Bozimowski, A. A., B. A. Murry, P. S. Kourtev, and D. G. Uzarski. 2014. Aquatic macroinvertebrate co-occurrence patterns in the coastal wetlands of the Great Lakes: the interaction of the harsh-benign hypothesis and community assembly rules. Great Lakes Science in Action Symposium, Central Michigan University, Mt. Pleasant, MI. April.

Bozimowski, A.A., B.A. Murry, P.S. Kourtev, and D.G. Uzarski. Aquatic macroinvertebrate co-occurrence patterns in the coastal wetlands of the Great Lakes. 58th International Conference on Great Lakes Research, Burlington, VT.

Bracey, A. M., R. W. Howe, N.G. Walton, E. E. G. Giese, and G. J. Niemi. Avian responses to landscape stressors in Great Lakes coastal wetlands. 5th International Partners in Flight Conference and Conservation Workshop. Snowbird, UT, August 25-28, 2013.

Brady, V., D. Uzarski, and M. Cooper. 2013. Great Lakes Coastal Wetland Monitoring: Assessment of High-variability Ecosystems. USEPA Mid-Continent Ecology Division Seminar Series, May 2013. 50 attendees, mostly scientists (INVITED).

Brady, V., G. Host, T. Brown, L. Johnson, G. Niemi. 2013. Ecological Restoration Efforts in the St. Louis River Estuary: Application of Great Lakes Monitoring Data. 5th Annual Conference on Ecosystem Restoration, Schaumburg, IL. July 30, 2013. 20 attendees, mostly managers and agency personnel.

Brady, V. and D. Uzarski. 2013. Great Lakes Coastal Wetland Fish and Invertebrate Condition. Midwestern State Wetland Managers Meeting, Kellogg Biological Station, Gull Lake, MI, October 31, 2013. 40 attendees; Great Lakes state wetland managers.

Brady, V., D. Uzarski, T. Brown, G. Niemi, M. Cooper, R. Howe, N. Danz, D. Wilcox, D. Albert, D. Tozer, G. Grabas, C. Ruetz, L. Johnson, J. Ciborowski, J. Haynes, G. Neuderfer, T. Gehring, J. Gathman, A. Moerke, G. Lamberti, C. Normant. 2013. A Biotic Monitoring Program for Great Lakes Coastal Wetlands. Society of Wetland Scientists annual meeting, Duluth, MN, June 2013. 25 attendees, mostly scientists, some agency personnel.

Brady, V., D. Uzarski, T. Brown, G. Niemi, M. Cooper, R. Howe, N. Danz, D. Wilcox, D. Albert, D. Tozer, G. Grabas, C. Ruetz, L. Johnson, J. Ciborowski, J. Haynes, G. Neuderfer, T. Gehring, J. Gathman, A. Moerke, G. Lamberti, C. Normant. 2013. Habitat Values Provided by Great Lakes Coastal Wetlands: based on the Great Lakes Coastal Wetland Monitoring Project. Society of Wetland Scientists annual meeting, Duluth, MN, June 2013. 20 attendees, mostly scientists.

Chorak, G.M., C.R. Ruetz III, R.A. Thum, J. Wesolek, and J. Dumke. 2015. Identification of brown and black bullheads: evaluating DNA barcoding. Poster presentation at the Annual Meeting of the Michigan Chapter of the American Fisheries Society, Bay City, Michigan. January 20-21.

Cooper, M.J. Great Lakes coastal wetland monitoring: chemical and physical parameters as co-variates and indicators of wetland health. Biennial State of the Lakes Ecosystem Conference, Erie, PA, October 26-27, 2011. Oral presentation.

Cooper, M.J. Coastal wetland monitoring: methodology and quality control. Great Lakes Coastal Wetland Monitoring Workshop, Traverse City, MI, August 30, 2011. Oral presentation.

Cooper, M.J., D.G. Uzarski, and G.L. Lamberti. GLRI: coastal wetland monitoring. Michigan Wetlands Association Annual Conference, Traverse City, MI, August 30-September 2, 2011. Oral presentation.

Cooper, M.J. Monitoring the status and trends of Great Lakes coastal wetland health: a basin-wide effort. Annual Great Lakes Conference, Institute of Water Research, Michigan State University, East Lansing, MI, March 8, 2011. Oral presentation.

Cooper, M.J., G.A. Lamberti, and D.G. Uzarski. Monitoring ecosystem health in Great Lakes coastal wetlands: a basin-wide effort at the intersection of ecology and management. Entomological Society of America, Reno, NV, November 13-16, 2011. Oral presentation

Cooper, M.J., and G.A. Lamberti. Taking the pulse of Great Lakes coastal wetlands: scientists tackle an epic monitoring challenge. Poster session at the annual meeting of the National Science Foundation Integrative Graduate Education and Research Traineeship Program, Washington, D.C., May 2012. Poster presentation.

Cooper, M.J., J.M. Kosiara, D.G. Uzarski, and G.A. Lamberti. Nitrogen and phosphorus conditions and nutrient limitation in coastal wetlands of Lakes Michigan and Huron. Annual meeting of the International Association for Great Lakes Research. Cornwall, Ontario. May 2012. Oral presentation.

Cooper, M.J., G.A. Lamberti, and D.G. Uzarski. Abiotic drivers and temporal variability of Saginaw Bay wetland invertebrate communities. International Association for Great Lakes Research, 56th annual meeting, West Lafayette, IN. June 2013. Oral presentation.

Cooper, M.J., D.G. Uzarski, J. Sherman, and D.A. Wilcox. Great Lakes coastal wetland monitoring program: support of restoration activities across the basin. National Conference on Ecosystem Restoration, Chicago, IL. July 2013. Oral presentation.

Cooper, M.J. and J. Kosiara. Great Lakes coastal wetland monitoring: Chemical and physical parameters as co-variates and indicators of wetland health. US EPA Region 5 Annual Wetlands Program Coordinating Meeting and Michigan Wetlands Association Annual Meeting. Kellogg Biological Station, Hickory Corners, MI. October 2013. Oral presentation.

Cooper, M.J. Implementing coastal wetland monitoring. Inter-agency Task Force on Data Quality for GLRI-Funded Habitat Projects. CSC Inc., Las Vegas, NV. November 2013. Web presentation, approximately 40 participants.

Cooper, M.J. Community structure and ecological significance of invertebrates in Great Lakes coastal wetlands. SUNY-Brockport, Brockport, NY. December 2013. Invited seminar.

Cooper, M.J. Great Lakes coastal wetlands: ecological monitoring and nutrient-limitation. Limno-Tech Inc., Ann Arbor, MI. December 2013. Invited seminar.

Cooper, M.J., D.G. Uzarski, and V.J. Brady. A basin-wide Great Lakes coastal wetland monitoring program: Measures of ecosystem health for conservation and management. Great Lakes Wetlands Day, Toronto, Ont. Canada, February 4, 2014. Oral presentation.

Cooper, M.J., G.A. Lamberti, and D.G. Uzarski. Supporting Great Lakes coastal wetland restoration with basin-wide monitoring. Great Lakes Science in Action Symposium. Central Michigan University. April 4, 2014.

Cooper, M.J. Expanding fish-based monitoring in Great Lakes coastal wetlands. Michigan Wetlands Association Annual Meeting. Grand Rapids, MI. August 27-29, 2014.

Cooper, M.J. Structure and function of Great Lakes coastal wetlands. Public seminar of Ph.D. dissertation research. University of Notre Dame. August 6, 2014.

Cooper, M.J., D.G. Uzarski, and T.N. Brown. Developing a decision support system for protection and restoration of Great Lakes coastal wetlands. Biodiversity without Borders Conference, NatureServe. Traverse City, MI. April 27, 2015.

Cooper, M.J. and D.G. Uzarski. Great Lakes coastal wetland monitoring for protection and restoration. Lake Superior Monitoring Symposium. Michigan Technological University. March 19, 2015.

Cooper, M.J. Where worlds collide: ecosystem structure and function at the land-water interface of the Laurentian Great Lakes. Central Michigan University Department of Biology. Public Seminar. February 5, 2015.

Cooper, M.J. Where worlds collide: ecosystem structure and function at the land-water interface of the Laurentian Great Lakes. Sigurd Olson Environmental Institute, Northland College. Public Seminar. May 4, 2015.

Cooper, M.J., and D.G. Uzarski. Great Lakes coastal wetland monitoring for protection and restoration. Lake Huron Restoration Meeting. Alpena, MI. May 14, 2015.

Cooper, M.J., D.G. Uzarski, and V.J. Brady. Developing a decision support system for restoration and protection of Great Lakes coastal wetlands. Wisconsin Wetlands Association Annual Meeting. February 24-25, 2016. Green Bay, WI.

Cooper, M.J., Stirratt, H., B. Krumwiede, and K. Kowalski. Great Lakes Resilient Lands and Waters Initiative, Deep Dive. Remote presentation to the White House Council on Environmental Quality and partner agencies, January 28, 2016.

Dahlberg, N., N.P. Danz, and S. Schooler. 2015. Integrating prior vegetation surveys from the St. Louis River estuary. Poster presentation at the 2015 Annual St. Louis River Summit, Superior, WI.

Danz, N.P. 2014. Floristic quality of Wisconsin coastal wetlands. Oral presentation at the Wisconsin Wetlands Association 19th Annual Wetlands Conference, LaCrosse, WI. Audience mostly scientists.

Danz, N.P. Floristic Quality of Coastal and Inland Wetlands of the Great Lakes Region. Invited presentation at the University of Minnesota Duluth, Duluth, MN.

Danz, N.P., S. Schooler, and N. Dahlberg. 2015. Floristic quality of St. Louis River estuary wetlands. Oral presentation at the 2015 Annual St. Louis River Summit, Superior, WI.

Danz, N.P. 2016. Floristic quality of St. Louis River estuary wetlands. Invited presentation at the Center for Water and the Environment, Natural Resources Research Institute, Duluth, MN.

Des Jardin, K. and D.A. Wilcox. 2014. Water chestnut: germination, competition, seed viability, and competition in Lake Ontario. New York State Wetlands Forum, Rochester, NY.

Dumke, J.D., V.J. Brady, J. Ciborowski, J. Gathman, J. Buckley, D. Uzarski, A. Moerke, C. Ruetz III. 2013. Fish communities of the upper Great Lakes: Lake Huron's Georgian Bay is an outlier. Society for Wetland Scientists, Duluth, Minnesota. 30 attendees, scientists and managers.

Dumke, J.D., V.J. Brady, R. Hell, A. Moerke, C. Ruetz III, D. Uzarski, J. Gathman, J. Ciborowski. 2013. A comparison of St. Louis River estuary and the upper Great Lakes fish communities (poster). Minnesota American Fisheries Society, St. Cloud, Minnesota. Attendees scientists, managers, and agency personnel.

Dumke, J.D., V.J. Brady, R. Hell, A. Moerke, C. Ruetz III, D. Uzarski, J. Gathman, J. Ciborowski. 2013. A comparison of wetland fish communities in the St. Louis River estuary and the upper Great Lakes. St. Louis River Estuary Summit, Superior, Wisconsin. 150 attendees, including scientists, managers, agency personnel, and others.

Dumke, J.D., V.J. Brady, J. Erickson, A. Bracey, N. Danz. 2014. Using non-degraded areas in the St. Louis River estuary to set biotic delisting/restoration targets. St. Louis River Estuary Summit, Superior, Wisconsin. 150 attendees, including scientists, managers, agency personnel, and others.

Dumke, J., C.R. Ruetz III, G.M. Chorak, R.A. Thum, and J. Wesolek. 2015. New information regarding identification of young brown and black bullheads. Oral presentation at the Annual Meeting of the Wisconsin Chapter of the American Fisheries Society, Eau Claire, Wisconsin. February 24-26. 150 attendees, including scientists, managers, agency personnel, and others.

Gathman, J.P. 2013. How healthy are Great Lakes wetlands? Using plant and animal indicators of ecological condition across the Great Lakes basin. Presentation to Minnesota Native Plant Society. November 7, 2013.

Gilbert, J.M., N. Vidler, P. Cloud Sr., D. Jacobs, E. Slavik, F. Letourneau, K. Alexander. 2014. *Phragmites australis* at the crossroads: Why we cannot afford to ignore this invasion. Great Lakes Wetlands Day Conference, Toronto, ON, February 4, 2014.

Gilbert, J.M. 2013. Phragmites Management in Ontario. Can we manage without herbicide? Webinar, Great Lakes *Phragmites* Collaborative, April 5, 2013.

Gilbert, J.M. 2012. *Phragmites australis*: a significant threat to Laurentian Great Lakes Wetlands, Oral Presentation, International Association of Great Lakes Wetlands, Cornwall, ON, May 2012

Gilbert, J.M. 2012. *Phragmites australis:* a significant threat to Laurentian Great Lakes Wetlands, Oral Presentation to Waterfowl and Wetlands Research, Management and Conservation in the Lower Great Lakes. Partners' Forum, St. Williams, ON, May 2012.

Gil de LaMadrid, D., and N.P. Danz. 2015. Water depth optima and tolerances for St. Louis River estuary wetland plants. Poster presentation at the 2015 Annual St. Louis River Summit, Superior, WI.

Gnass Giese, E.E. 2015. Great Lakes Wetland Frog Monitoring. Annual Lower Fox River Watershed Monitoring Program Symposium at the University of Wisconsin-Green Bay, Green Bay, Wisconsin. April 14, 2015. Oral Presentation.

Gnass Giese, E.E. 2015. Wetland Birds and Amphibians: Great Lakes Monitoring. Northeastern Wisconsin Audubon Society meeting at the Bay Beach Wildlife Sanctuary, Green Bay, Wisconsin. February 19, 2015. Oral Presentation.

Gnass Giese, E.E., R.W. Howe, N.G. Walton, G.J. Niemi, D.C. Tozer, W.B. Gaul, A. Bracey, J. Shrovnal, C.J. Norment, and T.M. Gehring. 2016. Assessing wetland health using breeding birds as indicators. Wisconsin Wetlands Association Conference, Radisson Hotel & Convention Center, Green Bay, Wisconsin. February 24, 2016. Poster Presentation.

Gnass Giese, E.E., R.W. Howe, A.T. Wolf, N.A. Miller, and N.G. Walton. An ecological index of forest health based on breeding birds. 2013. Webpage: http://www.uwgb.edu/biodiversity/forest-index/

Gurholt, C.G. and D.G. Uzarski. 2013. Into the future: Great Lakes coastal wetland seed banks. IGLR Graduate Symposium, Central Michigan University, Mt. Pleasant, MI. March.

Gurholt, C.G. and D.G. Uzarski. 2013. Seed Bank Purgatory: What Drives Compositional Change of Great Lakes Coastal Wetlands. 56th International Association for Great Lakes Research Conference, Purdue University, West Lafayette, IN. June.

Howe, R.W., R.P. Axler, V.J. Brady, T.N. Brown, J.J.H. Ciborowski, N.P. Danz, J.P. Gathman, G.E. Host, L.B. Johnson, K.E. Kovalenko, G.J. Niemi, and E.D. Reavie. 2012. Multi-species indicators of ecological condition in the coastal zone of the Laurentian Great Lakes. 97th Annual Meeting of the Ecological Society of America. Portland, OR.

Howe, R.W., G.J. Niemi, N.G. Walton, E.E.G. Giese, A.M. Bracey, V.J. Brady, T.N. Brown, J.J.H. Ciborowski, N.P. Danz, J.P. Gathman, G.E. Host, L.B. Johnson, K.E. Kovalenko, and E.D. Reavie. 2014. Measurable Responses of Great Lakes Coastal Wetland Biota to Environmental Stressors. International Association for Great Lakes Research Annual Conference, Hamilton, Ontario (Canada). May 26-30, 2014. Oral Presentation.

Howe, R.W., A.T. Wolf, and E.E. Gnass Giese. 2016. What's so special about Green Bay wetlands? Wisconsin Wetlands Association Conference, Radisson Hotel & Convention Center, Green Bay, Wisconsin. February 23-25, 2016. Oral Presentation.

Johnson, L., M. Cai, D. Allan, N. Danz, D. Uzarski. 2015. Use and interpretation of human disturbance gradients for condition assessment in Great Lakes coastal ecosystems. International Association for Great Lakes Research Conference, Burlington, VT.

Kosiara, J.M., M.J. Cooper, D.G. Uzarski, and G.A. Lamberti. 2013. Relationships between community metabolism and fish production in Great Lakes coastal wetlands. International Association for Great Lakes Research, 56th annual meeting. June 2-6, 2013. West Lafayette, IN. Poster presentation.

Lamberti, G.A., D.G. Uzarski, V.J. Brady, M.J. Cooper, T.N. Brown, L.B. Johnson, J.J. Ciborowski, G.P. Grabas, D.A. Wilcox, R.W. Howe, and D. C. Tozer. An integrated monitoring program for Great Lakes coastal wetlands. Society for Freshwater Science Annual Meeting. Jacksonville, FL. May 2013. Poster presentation.

Lamberti, G.A. Pacific Salmon in Natal Alaska and Introduced Great Lakes Ecosystems: The Good, the Bad, and the Ugly. Department of Biology, Brigham Young University. Dec 5, 2013. Invited seminar.

Lamberti, G. A. The Global Freshwater Crisis. The Richard Stockton College of New Jersey and South Jersey Notre Dame Club. November 18, 2014.

Lamberti, G. A. The Global Freshwater Crisis. Smithsonian Journey Group and several University Alumni Groups. March 1, 2015.

Lamberti, G. A. Pacific Salmon in Natal Alaska and Introduced Great Lakes Ecosystems: The Good, the Bad, and the Ugly. Annis Water Resources Institute, Grand Valley State University. December 12, 2014.

Langer, T.A., K. Pangle, B.A. Murray, and D.G. Uzarski. 2014. Beta Diversity of Great Lakes Coastal Wetland Communities: Spatiotemporal Structuring of Fish and Macroinvertebrate Assemblages. American Fisheries Society, Holland, MI. February.

Langer, T., K. Pangle, B. Murray, D. Uzarski. 2013. Spatiotemporal influences, diversity patterns and mechanisms structuring Great Lakes coastal wetland fish assemblages. Poster. Institute for Great Lakes Research 1st Symposium, MI. March.

Lemein, T.J., D.A. Albert, D.A. Wilcox, B.M. Mudrzynski, J. Gathman, N.P. Danz, D. Rokitnicki-Wojcik, and G.P. Grabas. 2014. Correlation of physical factors to coastal wetland vegetation community distribution in the Laurentian Great Lakes. Society of Wetland Scientists/Joint Aquatic Sciences Meeting, Portland, OR.

Mudrzynski, B.M., D.A. Wilcox, and A. Heminway. 2012. Habitats invaded by European frogbit (Hydrocharis morsus-ranae) in Lake Ontario coastal wetlands. INTECOL/Society of Wetland Scientists, Orlando, FL.

Mudrzynski, B.M., D.A. Wilcox, and A.W. Heminway. 2013. European frogbit (Hydrocharis morsus-ranae): current distribution and predicted expansion in the Great Lakes using niche-modeling. Society of Wetland Scientists, Duluth, MN.

Mudrzynski, B.M. and D.A. Wilcox. 2014. Effect of coefficient of conservatism list choice and hydrogeographic type on floristic quality assessment of Lake Ontario wetlands. Society of Wetland Scientists/Joint Aquatic Sciences Meeting, Portland, OR.

Mudrzynski, B.M., K. Des Jardin, and D.A. Wilcox. 2015. Predicting seed bank emergence within flooded zones of Lake Ontario wetlands under novel hydrologic conditions. Society of Wetlands Scientists. Providence, RI.

O'Reilly, K.E., A. McReynolds, and G.A. Lamberti. Quantifying Lake Michigan coastal wetland-nearshore linkages for sustaining sport fishes using stable isotope mixing models. Annual Meeting of the Ecological Society of America. Baltimore, MD. August 9-14, 2015.

O'Reilly, K.E., A. McReynolds, C. Stricker, and G.A. Lamberti. Quantifying Lake Michigan coastal wetland-nearshore linkages for sustaining sport fishes. State of Lake Michigan Conference. Traverse City, MI. October 28-30, 2015.

Schmidt, N. C., Schock, N., and D. G. Uzarski. 2013. Modeling macroinvertebrate functional feeding group assemblages in vegetation zones of Great Lakes coastal wetlands. International Association for Great Lakes Research Conference, West Lafayette, IN. June.

Schmidt, N.C., N.T. Schock, and D.G. Uzarski. 2014. Influences of metabolism on macroinvertebrate community structure across Great Lakes coastal wetland vegetation zones. Great Lakes Science in Action Symposium, Central Michigan University, Mt. Pleasant, MI. April.

Schock, N.T. and D.G. Uzarski. Stream/Drainage Ditch Impacts on Great Lakes Coastal Wetland Macroinvertebrate Community Composition. 55th International Conference on Great Lakes Research, Cornwall, Ontario.

Schock N.T., Uzarski D.G., 2013. Habitat conditions and macroinvertebrate communities of Great Lakes coastal habitats dominated by wet meadow, Typha spp. and Phragmites australis: implications of macrophyte structure changes. International Association for Great Lakes Research Conference, West Lafayette, IN. June.

Schock, N.T., B.A. Murry, D.G. Uzarski 2014. Impacts of agricultural drainage outlets on Great Lakes coastal wetlands. Great Lakes Science in Action Symposium, Central Michigan University, Mt. Pleasant, MI. April.

Schock, N.T., Schuberg, D.H., and Uzarski, D.G. 2015. Chemical and physical habitat gradients within Great Lakes coastal wetlands. 58th International Association for Great Lakes Research Conference, Burlington, VT. May.

Schoen, L.S., J.J. Student, and D.G. Uzarski. 2014. Reconstruction of fish movements between Great Lakes coastal wetlands. American Fisheries Society, Holland, MI. February.

Sherman, J.S., T.A. Clement, N.T. Schock, and D.G. Uzarski. 2012. A comparison of abiotic and biotic parameters of diked and adjacent open wetland complexes of the Erie Marsh Preserve. 55th International Conference on Great Lakes Research, Cornwall, Ontario.

Sherman, J.J., and D.G. Uzarski. 2013. A Comparison of Abiotic and Biotic Parameters of Diked and Adjacent Open Wetland Complexes of the Erie Marsh Preserve. 56th International Conference on Great Lakes Research, West Lafayette, IN. June.

Smith, D.L., M.J. Cooper, J.M. Kosiara, and G.A. Lamberti. 2013. Heavy metal contamination in Lake Michigan wetland turtles. International Association for Great Lakes Research, 56th annual meeting. June 2-6, 2013. West Lafayette, IN. Poster presentation.

Trebitz, A., J. Hoffman, G. Peterson, G. Shepard, A. Frankiewicz, B. Gilbertson, V. Brady, R. Hell, H. Wellard Kelly, and K. Schmude. 2015. The faucet snail (*Bithynia tentaculata*) invades the St. Louis River Estuary. St. Louis River Estuary Summit, Superior, Wisconsin. Mar. 30 – Apr. 1.

Tuttle, E., T.N. Brown, D.A. Albert, and *T.J. Lemein. 2013. Comparison of two plant indices: Floristic Quality Index (FQI) and an index based on non-native and invasive species. Annual Society of Wetland Scientists Conference, Duluth, MN. June 4, 2013.

Unitis, M.J., B.A. Murry and D.G. Uzarski. 2012. Use of coastal wetland types by juvenile fishes. Ecology and Evolutionary Ecology of Fishes, Windsor, Ontario. June 17-21.

Uzarski, D.G. 2011. Great Lakes Coastal Wetland Monitoring for Restoration and Protection: A Basin-Wide Effort. State Of the Lakes Ecosystem Conference (SOLEC). Erie, Pennsylvania. October 26.

Uzarski, D.G. 2011. Coastal Wetland Monitoring: Background and Design. Great Lakes Coastal Wetland Monitoring Meeting. MDEQ; ASWM. Acme, Michigan. August 29.

Uzarski, D.G., N.T. Schock, T.A. Clement, J.J. Sherman, M.J. Cooper, and B.A. Murry. 2012. Changes in Lake Huron Coastal Wetland Health Measured Over a Ten Year Period During Exotic Species Invasion. 55th International Conference on Great Lakes Research, Cornwall, Ontario.

Uzarski, D.G., M.J. Cooper, V.J. Brady, J. Sherman, and D.A. Wilcox. 2013. Use of a basin-wide Great Lakes coastal wetland monitoring program to inform and evaluate protection and restoration efforts. International Association for Great Lakes Research, West Lafayette, IN. (INVITED)

Uzarski, D.G. 2013. A Basin Wide Great Lakes Coastal Wetland Monitoring Plan. Region 5 State and Tribal Wetlands Meeting: Focusing on Wetland Monitoring and Assessment around the Great Lakes. October 31. Kellogg Biological Station, Hickory Corners, MI.

Uzarski, D.G. 2013. Great Lakes Coastal Wetland Assessments. Lake Superior Cooperative Science and Monitoring Workshop. September 24-25. EPA Mid-Continent Ecology Division Lab, Duluth, MN.

Uzarski, D.G. 2013. A Basin-Wide Great Lakes Coastal Wetland Monitoring Program. 5th National Conference on Ecosystem Restoration. July 29-August 2. Schaumburg, IL.

Uzarski, D.G., Cooper, M.J., Brady, V., Sherman, J.J., and D.A. Wilcox. 2013. Use of a Basin Wide Great Lakes Coastal Wetland Monitoring Program to inform and Evaluate Protection and Restoration Efforts. 56th International Conference on Great Lakes Research, West Lafayette, IN.

Uzarski, D., M. Cooper and V. Brady. 2014. Implementing a Basin-wide Great Lakes Coastal Wetland Monitoring Program. Webinar for Sustain Our Great Lakes, Jan. 29, 2014. On-line webinar for Great Lakes researchers, managers, agency personnel, and environmental groups. Attendance approximately 400.

Uzarski, D.G., Schock, N.T., Schuberg, D.H., Clement, T.A., and Cooper, M.J. 2015. Interpreting multiple organism-based IBIs and disturbance gradients: Basin wide monitoring. 58th International Conference on Great Lakes Research, Burlington, VT. May.

Walton, N.G., E.E.G. Giese, R.W. Howe, G.J. Niemi, N.P. Danz, V.J. Brady, T.N. Brown, J.H. Ciborowski, J.P. Gathman, G.E. Host, L.B. Johnson, E.D. Reavie, and K.E. Kovalenko. 2013. How do different taxa respond to landscape stressors in Great Lakes coastal wetlands? 98th Annual Meeting of the Ecological Society of America. Minneapolis, MN, August 4-9.

Webster, W.C. and D.G. Uzarski. 2012. Impacts of Low Water level Induced Disturbance on Coastal Wetland Vegetation. 55th International Conference on Great Lakes Research, Cornwall, Ontario.

Wheeler, R. and D.G. Uzarski. 2012. Spatial Variation of Macroinvertebrate Communities within Two Emergent Plant Zones of Great Lakes Coastal Wetlands. 55th International Conference on Great Lakes Research, Cornwall, Ontario.

Wheeler, R.L. and D.G. Uzarski. 2013. Effects of Vegetation Zone Size on a Macroinvertebrate-based Index of Biotic Integrity for Great Lakes Coastal Wetlands. 56th International Conference on Great Lakes Research, West Lafayette, IN. June.

Wilcox, D.A. and B.M. Mudrzynski. 2011. Wetland vegetation sampling protocols under the Great Lakes Coastal Wetland Monitoring program: experience in Lake Ontario. State of the Lakes Ecosystem Conference, Erie, PA. (INVITED)

Wilcox, D.A. and B.M. Mudrzynski. 2012. Implementing Great Lakes coastal wetlands monitoring: southern Lake Ontario. SUNY Great Lakes Research Consortium Conference, Oswego, NY. (INVITED)

Wilcox, D.A. 2012. Wetland restoration options under the Great Lakes Restoration Initiative. SUNY Great Lakes Research Consortium Conference, Oswego, NY. (INVITED)

Wilcox, D.A., D.G. Uzarski, V.J. Brady, M.J. Cooper, and T.N. Brown. 2013. Great Lakes coastal wetland monitoring program assists restoration efforts. Fifth World Conference on Ecological Restoration, Madison, WI.

Wilcox, D.A., D.G. Uzarski, V.J. Brady, M.J. Cooper, and T.N. Brown. 2014. Wetland restoration enhanced by Great Lakes coastal wetland monitoring program. Society of Wetland Scientists, Portland, OR.

Wilcox, D.A. 2015. Wetland restorations in the Braddock Bay Fish and Wildlife Management Area of Lake Ontario. NY Waterfowl and Wetland Collaborative

Network, Oswego, NY. (INVITED)

Publications/Manuscripts

Bracey, A.M., G.J. Niemi, M.A. Etterson, and R.F. Green. 2016. Window related avian mortality at a migration corridor. The Wilson Journal of Ornithology 128:355-367.

Bracey A.M., Kovalenko K.E., Howe R.W., Niemi G.J. 2017. Disruption of breeding bird functions due to human disturbance across a large coastal region. In preparation.

Chin, A.T.M., D.C. Tozer, N.G. Walton, and G.S. Fraser. 2015. Comparing disturbance gradients and bird-based indices of biotic integrity for ranking the ecological integrity of Great Lakes coastal wetlands. Ecological Indicators 57:475-485.

Chin, A.T.M., D.C. Tozer, and G.S. Fraser. 2014. Hydrology influences generalist-specialist bird-based indices of biotic integrity in Great Lakes coastal wetlands. Journal of Great Lakes Research 40:281-287.

Cooper, M.J., and D.G. Uzarski. 2016. Invertebrates in Great Lakes Marshes. Invertebrates in Freshwater Marshes: An International Perspective on their Ecology: D. Batzer (ed). Springer.

Cooper, M.J., G.A. Lamberti, and D.G. Uzarski. 2014. Spatial and temporal trends in invertebrate communities of Great Lakes coastal wetlands, with emphasis on Saginaw Bay of Lake Huron. *Journal of Great Lakes Research Supplement* 40:168–182.

Cooper, M.J., G.M. Costello, S.N. Francoeur, and G.A. Lamberti. 2016. Nitrogen limitation of algal biofilms in coastal wetlands of Lakes Michigan and Huron. *Freshwater Science* 35(1).

Cooper, M.J., and 10 others. In revision. An expanded fish-based index of biotic integrity for Great Lakes coastal wetlands. *Wetlands*.

Dumke, J., V. Brady, N. Danz, A. Bracey, G. Niemi. 2014. St. Louis River Report: Clough Island. NRRI TR2014/26 for Wisconsin DNR.

Engstrom, R.T. and G.J. Niemi. 2015. Book Review: Decision making in natural resource management: a structured, adaptive approach. The Condor 117: 482-483.

Falconer, C.M., G.W. Mitchell, P.D. Taylor, D.C. Tozer. 2016. Prevalence of disjunct roosting in breeding Bank Swallows. Wilson Journal of Ornithology 128:429-434.

Gnass Giese, E.E., R.W. Howe, A.T. Wolf, N.A. Miller, and N.G. Walton. 2015. Sensitivity of breeding birds to the ''human footprint'' in western Great Lakes forest landscapes. Ecosphere 6(6):90. http://dx.doi.org/10.1890/ES14-00414.1

Grinde, A.R., G.J. Niemi. A synthesis of species interactions, metacommunities, and the conservation of avian diversity in hemiboreal and boreal forests. Journal of Avian Biology 47:1-13.

Niemi, G.J., L.B. Johnson, R.W. Howe. 2015. Chapter 16 - Environmental indicators of land cover, land use, and landscape change. Pages 265-276 in Armon R. and O. Hanninen (eds.) Environmental indicators, Springer, Dordrecht, 1068 pp.

Panci, H., G.J. Niemi, R.R. Regal, D.C.Tozer, R.W. Howe, C.J. Norment, T.M. Gehring. 2017. Influence of local-and landscape-scale habitat on Sedge and Marsh Wren occurrence in Great Lakes coastal wetlands. Wetlands: accepted pending final revisions.

Smith, D.L, M.J. Cooper, J.M. Kosiara, and G.A. Lamberti. 2016. Body burdens of heavy metals in Lake Michigan wetland turtles. *Environmental Monitoring and Assessment* 188:128.

Tozer, D.C., R.W. Howe, G.J. Niemi, E.E.G. Giese, N.G. Walton, A.M. Bracey, W. Gaul, C.J. Norment, T.M. Gehring. 2015. Coastal wetland birds. State of the Great Lakes 2017 – Draft. US. EPA and Environment Canada. 15 p.

Tozer, D.C., R.W. Howe, G.J. Niemi, E.E.G. Giese, N.G. Walton, A.M. Bracey, W. Gaul, C.J. Norment, T.M. Gehring. 2015. Coastal wetland amphibians. State of the Great Lakes 2017 – Draft. US. EPA and Environment Canada. 10 p.

Tozer, D.C., O. Steele, M. Gloutney. 2017. Multispecies benefits of wetland conservation for marsh birds, frogs, and species at risk. Wetlands Ecology and Management: submitted.

Tozer, D.C., K.L. Drake, and C.M. Falconer. 2016. Modeling detection probability to improve marsh bird surveys in southern Canada and the Great Lakes states. Avian Conservation and Ecology 11:2.

Tozer, D.C. 2016. Marsh bird occupancy dynamics, trends, and conservation in the southern Great Lakes basin: 1996 to 2013. Journal of Great Lakes Research 42:136-145.

Walpole, A., J. Bowman, D. Tozer, and D. Badzinski. 2012. Community level response to climate change: shifts in anuran calling phenology. Herpetological Conservation and Biology 7:249-257.

Tozer, D.C., A.M.Bracey, E.E.Gnass Giese, G.J. Niemi, R.W.Howe, T.M.Gehring, and C.J. Norment. 2017. Influence of broadcast timing and point count duration on marsh bird survey results. Avian Conservation and Ecology: submitted.

Uzarski, D., V. Brady, M. Cooper, D.A.Wilcox, D. Albert, R.Axler, P. Bostwick, T.Brown, J.Ciborowski, N.Danz, J.Gathman, T.Gehring, G.Grabas, .Garwood,R.Howe, L.Johnson, G.Lamberti, A.Moerke, B.Murry, G.Niemi, C.Norment, C.Ruetz, A.Steinman, D. Tozer, R.Wheeler, T.K.O'Donnell, J.P.Schneider. 2016. Standardization measures of ecosystem health: Great Lakes Coastal Wetland Consortium. Wetlands: in press.

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Crewe, T.L. and Timmermans, S.T.A. 2005. Assessing Biological Integrity of Great Lakes Coastal Wetlands Using Marsh Bird and Amphibian Communities.Bird Studies Canada, Port Rowan, Ontario. 89pp.

Danz, N.P., G.J. Niemi, R. R. Regal, T. Hollenhorst, L. B. Johnson, J.M. Hanowski, R.P. Axler, J.J.H. Ciborowski, T. Hrabik, V.J. Brady, J.R. Kelly, J.A. Morrice, J.C. Brazner, R.W. Howe, C.A. Johnston and G.E. Host. 2007. Integrated Measures of Anthropogenic Stress in the U.S. Great Lakes Basin. Environ Manage. 39:631–647.

Elias, J. E, R. Axler, and E. Ruzycki. 2008. Water quality monitoring protocol for inland lakes. Version 1.0. National Park Service, Great Lakes Inventory and Monitoring Network. Natural Resources Technical Report NPS/GLKN/NRTR—2008/109. National Park Service, Fort Collins, Colorado.

Farnsworth, G.L., K.H. Pollock, J.D. Nichols, T.R. Simons, J.E. Hines, and J.R. Sauer. 2002. A removal model for estimating detection probabilities from point-count surveys. Auk 119:414-425.

Gnass Giese, E.E., R.W. Howe, A.T. Wolf, N.A. Miller, N.G. Walton. 2015. Sensitivity of breeding birds to the “human footprint” in western Great Lakes forest landscapes. Ecosphere 6: 90. http://dx.doi.org/10.1890/ES14-00414.1.

Howe, R.W., R. R. Regal, J.M. Hanowski, G.J. Niemi, N.P. Danz, and C.R. Smith. 2007a. An index of ecological condition based on bird assemblages in Great Lakes coastal wetlands. Journal of Great Lakes Research 33 (Special Issue 3): 93-105.

Howe, R.W., R. R. Regal, G.J. Niemi, N.P. Danz, J.M. Hanowski. 2007b. A probability-based indicator of ecological condition. Ecological Indicators 7:793-806.

Karr, J.R., 1981. Assessment of biotic integrity using fish communities. Fisheries 6: 21–27.

Lyons, J. 2012. Development and validation of two fish-based indices of biotic integrity for assessing perennial coolwater streams in Wisconsin, USA. Ecological Indicators 23: 402-412.

Morrice, J.A., N.P. Danz, R.R. Regal, J.R. Kelly, G.J Niemi, E.D. Reavie, T. Hollenhorst, R.P. Axler, A.S. Trebitz, A.M. Cotter, and G.S. Peterson. 2008. Human influences on water quality in Great Lakes coastal wetlands. Environmental Management 41:347–357.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Map (scale 1:7,500,000). Annals of the Association of American Geographers 77(1):118-125.

Reavie, E., R. Axler, G. Sgro, N. Danz, J. Kingston, A. Kireta, T. Brown, T. Hollenhorst and M. Ferguson. 2006. Diatom-base weighted-averaging models for Great Lakes coastal water quality: Relationships to watershed characteristics. J. Great Lakes Research 32:321–347.

Tozer, D.C., R.W. Howe, G.J. Niemi, E.E. Gnass Giese, N.G. Walton, A.M. Bracey, W. Gaul, C.J. Norment, and T.M. Gehring. 2015. Coastal Wetland Birds. In State of the Great Lakes 2017, Environmental Canada and U.S. Environmental Protection Agency, draft report. Tozer, D.C., 2016. *Marsh bird occupancy dynamics, trends, and conservation in the southern Great Lakes basin: 1996 to 2013.* J. Great Lakes Res. 42, in press.

Trebitz, A., G. Shepard, V. Brady, K. Schmude. 2015. The non-native faucet snail (*Bithynia tentaculata*) makes the leap to Lake Superior. J. Great Lakes Res. 41, 1197-1200.

United States Environmental Protection Agency. 2002. Methods for Evaluating Wetland Condition: Developing Metrics and Indexes of Biological Integrity. Office of Water, United States Environmental Protection Agency. Washington, DC. EPA-822-R-02-016.

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Appendix

News articles about faucet snail detection in Great Lakes coastal wetlands.

1. http://www.upnorthlive.com/news/story.aspx?id=1136758
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Mock-up of press release produced by collaborating universities.

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USEPA-sponsored project greatly expands known locations of invasive snail

DULUTH, Minn. – Several federal agencies carefully track the spread of non-native species. This week scientists funded by the Great Lakes Restoration Initiative in partnership with USEPA's Great Lakes National Program Office greatly added to the list of known locations of faucet snails (*Bithynia tentaculata*) in the Great Lakes. The new locations show that the snails have invaded many more areas along the Great Lakes coastline than anyone realized.

The spread of these small European snails is bad news for water fowl: They are known to carry intestinal flukes that kill ducks and coots.

"We've been noting the presence of faucet snails since 2011 but didn't realize that they hadn't been officially reported from our study sites," explained Valerie Brady, NRRI aquatic ecologist who is collaborating with a team of researchers in collecting plant and animal data from Great Lakes coastal wetlands.

Research teams from 10 universities and Environment Canada have been sampling coastal wetlands all along the Great Lakes coast since 2011 and have found snails at up to a dozen sites per year [See map 1]. This compares to the current known locations shown on the USGS website [see map 2].

"Our project design will, over 5 years, take us to every major coastal wetland in the Great Lakes. These locations are shallow, mucky and full of plants, so we're slogging around, getting dirty, in places other people don't go. That could be why we found the snails in so many new locations," explained Bob Hell, NRRI's lead macroinvertebrate taxonomist. "Luckily, they're not hard to identify."

The small snail, 12 – 15 mm in height at full size, is brown to black in color with a distinctive whorl of concentric circles on the shell opening cover that looks like tree rings. The tiny size of young snails means they are easily transported and spread, and they are difficult to kill.

According to the Minnesota Department of Natural Resources, the faucet snail carries three intestinal trematodes that cause mortality in ducks and coots. When waterfowl consume the infected snails, the adult trematodes attack the internal organs, causing lesions and hemorrhage. Infected birds appear lethargic and have difficulty diving and flying before eventually dying.

Although the primary purpose of the project is to assess how Great Lakes coastal wetlands are faring, detecting invasives and their spread is one of the secondary benefits. The scientific team expects to report soon on the spread of non-native fish, and has helped to locate and combat invasive aquatic plants.

“Humans are a global species that moves plants and animals around, even when we don’t mean to. We’re basically homogenizing the world, to the detriment of native species,” Brady added, underscoring the importance of knowing how to keep from spreading invasive species. Hell noted, “We have to make sure we all clean everything thoroughly before we move to another location.”

For more information on how to clean gear and boats to prevent invasive species spread, go to www.protectyourwaters.net.