GLIC: Implementing Great Lakes Coastal Wetland Monitoring

Semiannual Progress Report

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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 has 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.

There have been no changes to our project's objectives.

Summary of past activities:
Our primary activities in our first year involved developing our Quality Assurance Project Plan (signed March 21, 2011), developing the site selection mechanism, selecting our sites, and conducting our field work (wetland sampling), which began in late April/early May and continued through mid-September, 2011. All primary project personnel met in mid-January of 2011 to work through methods and details of all aspects of the project. During the first year, crews successfully sampled 176 sites with crew members that had completed extensive training sessions and passed all training requirements, including field sampling and identification tests. Crews then successfully entered the field data and completed quality control procedures and identified macroinvertebrate samples and entered those data.

During our second year, we revised and updated our QAPP (signed March 28, 2012), updated our site selection system to include site revisits that will help track wetland condition through time and assess year-to-year variability at the site level, and held a meeting with all project lead personnel (February 2012) to find solutions to issues that arose during our first year. In our second field season, we sampled 206 sites. Teams entered and QC'd all of the data from the second field season, and PIs resolved taxonomic issues that arose. Data managers and programmers enabled calculation of most metrics and IBIs within the project database.

During our third year, PIs worked on metrics specific to vegetation zones that currently lack IBIs. As part of this process, we began investigating the stability of metrics based on a comparison of the data from the original sampling and site re-visits. All co-PIs and many field crew leaders met in the Detroit area (January 2013). Our QAPP did not need to be updated, and all co-PIs re-signed it March 2013. Our site selection system required minor modification to better handle benchmark sites (sites of special interest for restoration or protection).
244 sites were selected for potential sampling. Of these, 32 were benchmark sites and 12 were temporal re-sample sites, with the remaining 200 sites selected by the original "random draw" that placed sites in the sampling panels. 201 of these sites were sampleable in 2013.

During our fourth year, project PIs and field crew chiefs again met (Midland Michigan, January 15, 2014) to discuss aspects of the project needing attention and to help ensure that all teams continue to sample in the same manner across the entire Great Lakes basin. Topics at the 2014 meeting included adding other options for some of the water quality analyses (the QAPP and water quality SOP were updated for this purpose in March 2014), and issues with hybridization among fish species within certain genera (bullheads, gar, sunfishes). Site selection resulted in 251 sites, and of these we sampled 216 sites.

During our fifth year, project PIs and field crew chiefs again met (Midland Michigan, 2015) to revisit methods and metrics. These meetings help keep all teams sampling in the same way across the basin, although such sampling has become routine for the field crews. As scientists, the PIs continually search for ways to extend the metrics into other habitats or to refine their interpretation. Topics of discussion in 2015 included manuscripts in process, benchmark site sampling, data analysis, and conclusions, along with EPA's desire that we assist with the assessment of future coastal wetland restoration projects. The QAPP (Rev. 5) was revised to update personnel changes and to provide an alternate vegetation sampling protocol for wide, dense *Phragmites* stands. Site selection resulted in an initial draw of 260 sites, of which 211 were sampled.

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). No major personnel changes have taken place during this reporting period, although 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.

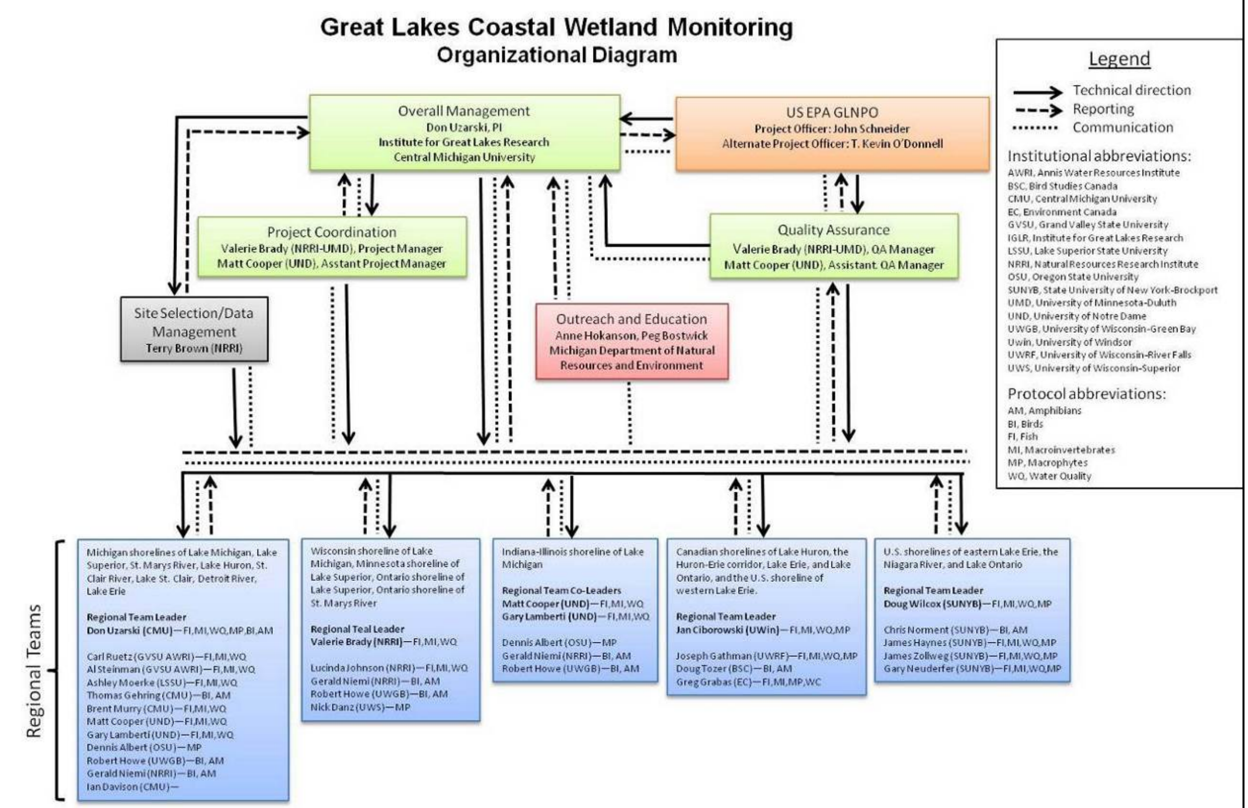

Figure 1. Organizational chart for the project showing lines of technical direction, reporting, and communication separately.

PROJECT TIMELINE

The project timeline remains unchanged and we are on-schedule (Table 1).

Table 1. Timeline of tasks and deliverables for the Great Lakes Coastal Wetland Monitoring Project.

Tasks	‘10	2011				2012				2013				2014				2015			
	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F
Funding received	X																				
PI meeting		X				X				X				X				X			X
Site selection system designed		X																			
Site selection implemented			X			X				X				X				X			
Sampling permits acquired			X				X				X				X				X		
Data entry system created			X	X																	
Field crew training			X	X			X	X			X	X			X	X			X	X	
Wetland sampling			X	X			X	X			X	X			X	X			X	X	
Mid-season QA/QC evaluations				X				X				X				X				X	
Sample processing & QC					X	X			X	X			X	X			X	X			X
Data QC & upload to GLNPO						X	X			X	X			X	X			X	X		X
GLAS database report		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Report to GLNPO			X		X		X		X		X		X		X		X		X		X

SITE SELECTION

Year six site selection was completed in March 2016. Because we completed the original Coastal Wetland Monitoring site list in 2015 (year 5), we are now starting the list again. In 2016, we will be sampling the same site list as was generated for 2011, with a few benchmark site additions that we did not have in 2011. Benchmark sites (sites of special interest for restoration or protection) can be sampled more than once in the five year sampling rotation, and may be sites that were not on the original sampling list. The selection modification for these sites involved specifying exactly which teams will sample these sites each year, allowing bird and amphibian crews, which have greater sampling capacity, to visit these sites more often than other crews.

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 2). See the QAPP for a thorough description of site selection criteria.

Table 2. 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 2). 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 rapidly due to a combination of glacial rebound and topography that limits the potential for coastal wetlands to migrate downslope with falling water levels. 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 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. 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 ecoregions 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 3.

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 3. 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 4. 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 4. 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.

2016 Site Selection

For 2016, 213 sites have been initially selected for sampling (Figure 3). Of these, 22 are benchmark sites. Another 16 sites are resample sites. New this year, we have labeled resample sites for the next year (2017) as Pre-sample sites (P). Benchmark, resample, and pre-sample sites are sorted to the top of the sampling list because they are the highest priority sites to be sampled. By sorting next year's resample sites to the top of the list, this will help ensure that most crews sample them in 2016, allowing more complete comparison of year-year variation when the sites are sampled again the next year. Because the vast majority of the 2016 sites were sampled in 2011, we do not expect very many sites to be dropped due to inaccessibility or not meeting our sampling criteria.

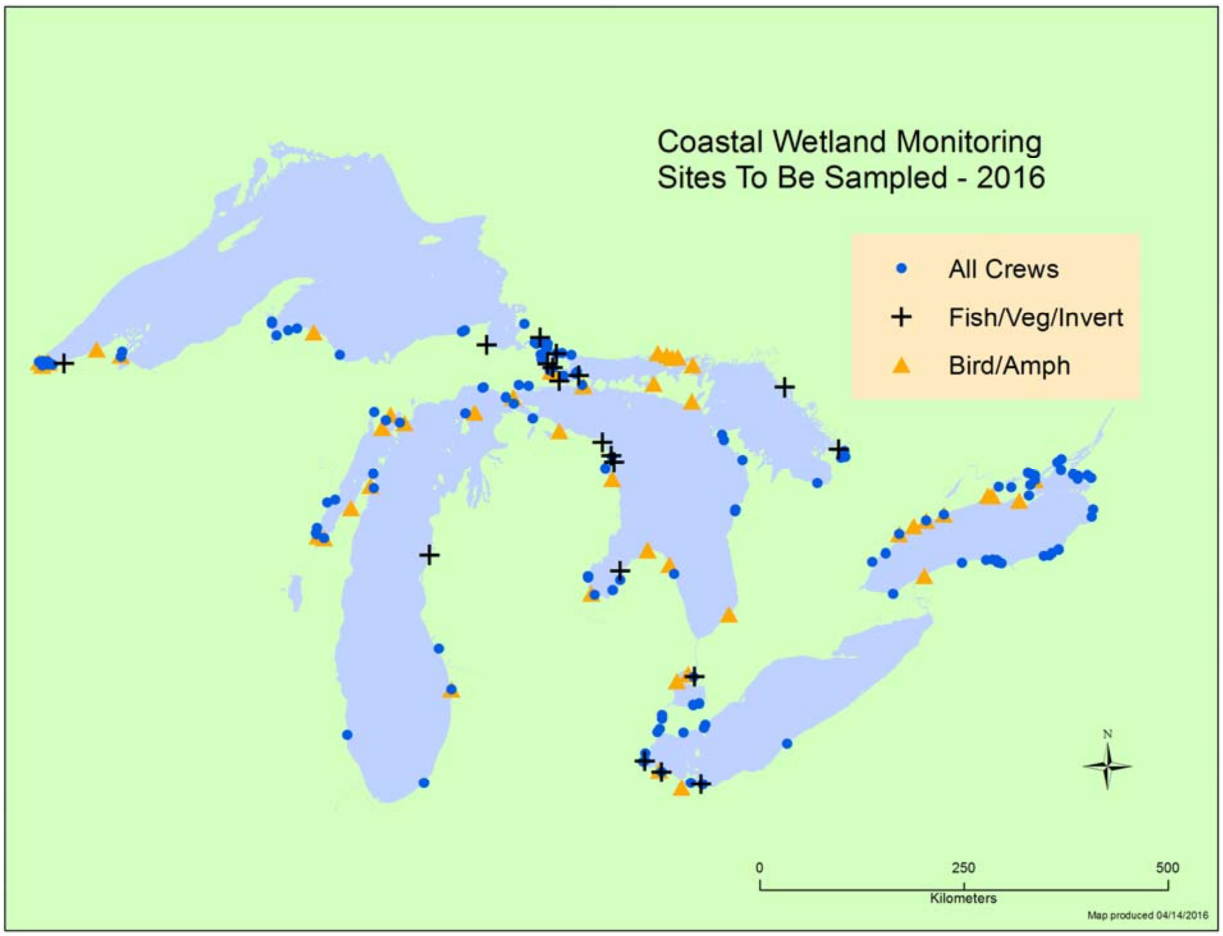

Figure 3. Locations of the 213 Great Lakes coastal wetlands to be sampled in 2016, color-coded by taxonomic groups. Sites assigned only to bird and amphibian crews (due to their greater sampling capacity) are shown with a gold triangle.

Wetlands have a "clustered" distribution around the Great Lakes due to geological differences. Thus, each year several teams ended up with fewer sites than they had the capacity to sample, while other teams' assigned sites exceed their sampling capacity. Within reason, teams with excess sampling capacity will expand their sampling boundaries to assist neighboring over-capacity teams in order to maximize the number of wetlands sampled. The site selection and site status tools are used to make these changes.

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. Now that PIs and crew chiefs are experienced, field crew training is being handled by each PI at each regional location. All crew members still must pass all training tests, and PIs still conduct mid-season QC. Trainers are available each season if a crew has substantial turnover and training assistance is needed. As has become standard protocol, the trainers will always be available via phone and email to answer any questions that arise during training sessions or during the field season.

The following is a synopsis of the training to be conducted by PIs this spring (2016): Each PI or field crew chief trains all field personnel on meeting the data quality objectives for each element of the project; this includes 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 will be required to pass all training certifications before they are allowed to work unsupervised. Those who do not pass all training aspects are only allowed to work under the supervision of a crew leader who has passed all training certifications.

Training for bird and amphibian field crews includes 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 are tested for proficiency in completing field sheets, and audio testing is done to ensure their hearing is within the normal ranges. Field training will also be completed to ensure guidelines in the QAPP are 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 will be trained on field and laboratory protocols. Field training includes selecting appropriate sampling locations, setting fyke nets, identifying fish, sampling and sorting invertebrates, and collecting water quality and habitat covariate data. Laboratory training includes preparing water samples, titrating for alkalinity, and filtering for chlorophyll. Other training includes GPS use, safety and boating issues, field sheet completion, and GPS and records uploading. All crew members are required to be certified in each respective protocol prior to working independently.

Vegetation crew training also includes both field and laboratory components. Crews are trained in field sheet completion, transect and point location and sampling, GPS use, and plant curation. Plant identification will be tested following phenology through the first part of the field season. All crew members must 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 has successfully uploaded data each year. The re-created data entry database is very similar to the original database, but update training will be provided via webinar as each taxonomic group wraps up their field season and starts data entry.

Certification

To be certified in a given protocol, individuals must pass a practical exam. Certification exams are conducted in the field in most cases, either during training workshops or during site visits early in the season. When necessary, exams are supplemented with photographs (for fish and vegetation) or audio recordings (for bird and amphibian calls). Passing a given exam certifies the individual to perform the respective sampling protocol(s). Since not every individual is responsible for conducting every sampling protocol, crew members are only tested on the protocols for which they are responsible. Personnel who are not certified (e.g., part-time technicians, new students, volunteers) will 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 is considered adequate for certification. Training and certification records for all participants are 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 requires 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 archive copies of the testing and certification records of all field crew members. Summaries of these records are also archived with the lead PI (Uzarski), and the QA managers (Brady and Cooper).

Web-based Data Entry System

We have been 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 is 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 groups' data.

The web-based data retrieval system for project researchers allows "raw", QC'd data to be downloaded by PIs of each taxonomic group. Additionally, most of the metric and IBI calculations have been automated and can be generated simply by re-running the scripts. The data retrieval system uses the same technologies as the data entry system. Password access is tracked separately for the data retrieval system, and is again tracked individually.

EPA GLNPO has been given access to the retrieval system and data, located at http://beaver.nrri.umn.edu/glrimon/dv/folder/. 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.

Data is continuously backed up using a live backup system (Write Ahead Log storage from the database backend), with nightly mirroring of the backup system to a separate location (from NRRI to the UMD campus).

The above system was used for data entry through the data collected in the 2015 field season. We are now switching over to an updated database and web interface developed for the project by LimnoTech Inc., which will provide improved functionality and security. LimnoTech has also developed an updated interactive map for data visualization. These new systems are coming on-line right now. The data entry system has been tested by several experienced data entry personnel at CMU and NRRI, and will be available for data entry for the 2016 sampling season.

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 5). Note that this is not the same as the number of unique wetlands sampled because of temporal re-sampling events and benchmark sites that are sampled in more than one year.

As in previous 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 tend to be larger (see area percentages, Table 5). When compared to the total number of wetlands targeted to be sampled by this project (Table 2), we are achieving our goals of sampling 20% of US wetlands per year, both by count and by area. However, 66% of total sites sampled have been US coastal wetlands, with 80% of the wetland area sampled on the US side. Overall, not yet correcting for sites that have been sampled more than once, we have sampled about 80%

of US coastal wetlands by count and by area. With respect to the entire Great Lakes, the project has sampled about 80% of coastal wetlands by count and area.

Table 5. 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. 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**	

Teams may have been able to sample more sites in 2014 and 2015 due to higher lake levels on Lakes Michigan and Huron, which allowed crews to access sites and areas that have 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.

The sites sampled in 2015 are shown in Figures 4 and 5 and are color coded by which taxonomic groups were sampled at the sites and by wetland types, respectively. 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 are also a number of sites sampled only by bird and amphibian crews because these crews can complete their site sampling more quickly and thus have the capacity to sample more sites than do the fish, macroinvertebrate, and vegetation crews.

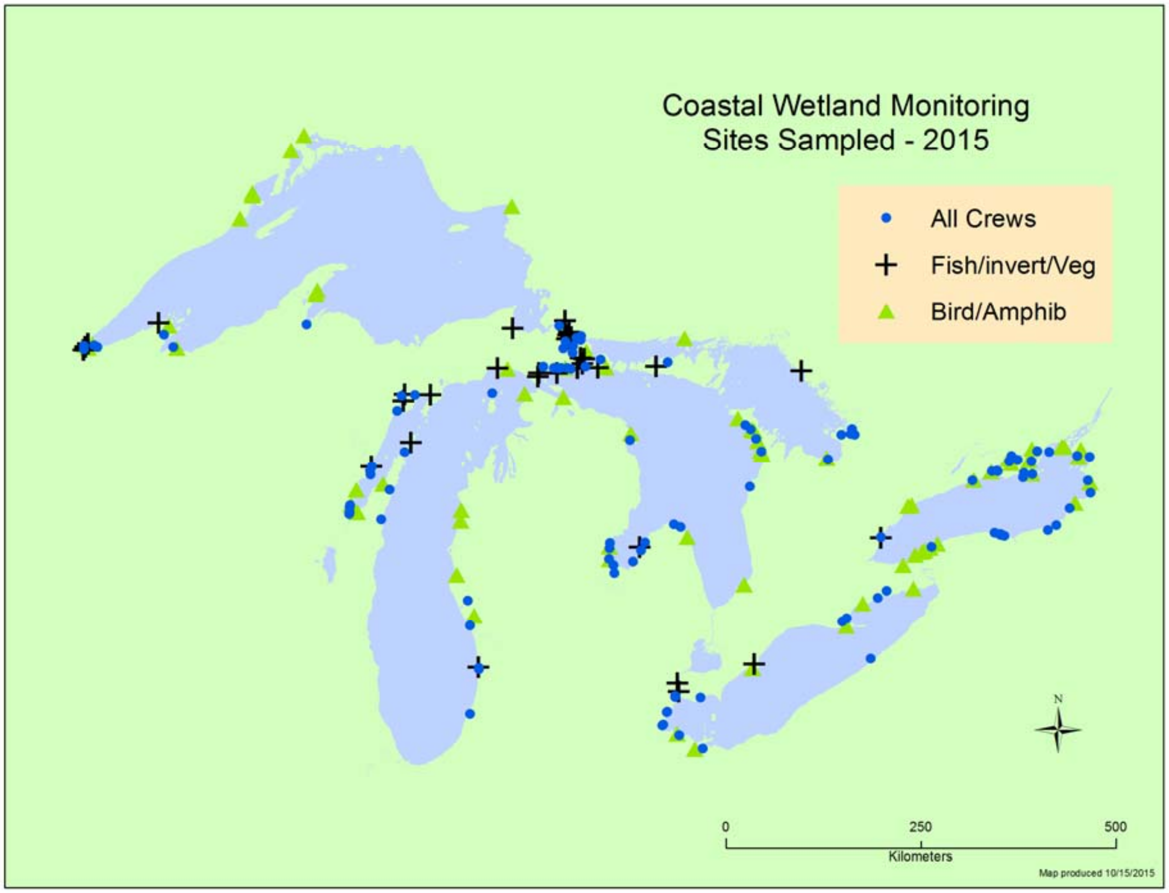

Figure 4. Locations of the 211 Great Lakes coastal wetlands sampled in 2015, color-coded by taxonomic groups. Sites assigned only to bird and amphibian crews (due to their greater sampling capacity) are shown with a green triangle.

Wetland types are not distributed evenly across the Great Lakes due to fetch, topography, and geology (Figure 5). 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.

Benchmark sites are sites that are either added to the overall site list and would not have been sampled as part of the random selection process, or are sites that are considered a reference of some type and are being sampled more frequently. Sites that would not have been sampled typically were too small, disconnected from lake influence, or are not a wetland at this time, and thus did not fit the protocol. These sites are 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 are getting many requests to provide baseline data for restoration work; this is occurring at a frequency great enough for us to have difficulty accommodating the extra effort.

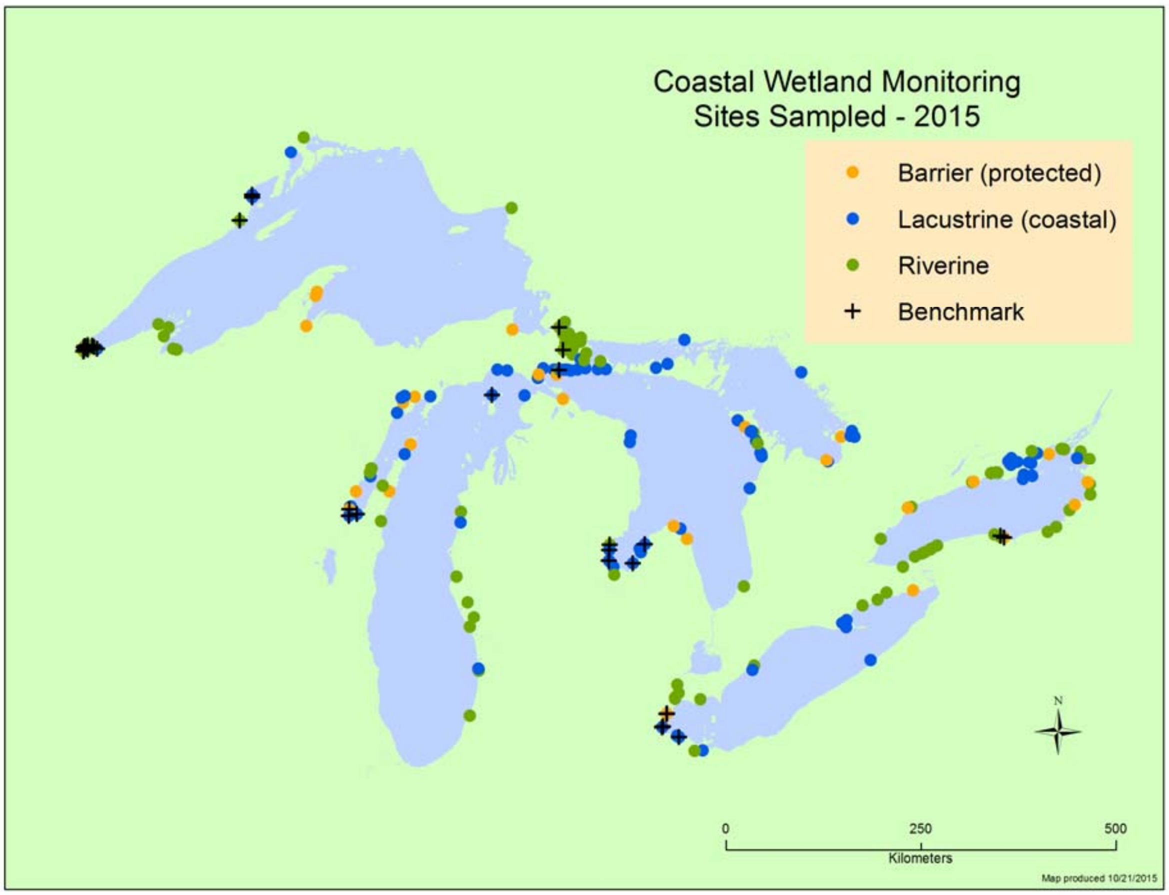

Figure 5. Locations of the 211 Great Lakes coastal wetlands sampled in 2015, color-coded by site type. Wetland types exhibit a clumped distribution across lakes due to geology and topography.

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

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 in 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 are a number of benchmark sites that are being sampled every year or every other year to collect extra data on these locations. Thus, we are adding relatively few new sites as benchmarks each year. These tend to be sites that are 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 6). 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 6). However, there were wetlands where all 8 calling amphibian species were heard over the three sampling dates.

Table 6. 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 7) 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 7). Similarly, there was little variability by lake in maximum or minimum numbers of species. At some benchmark sites and cold springs no calling amphibians were detected.

Table 7. 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 8). 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 8. 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 6). 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.

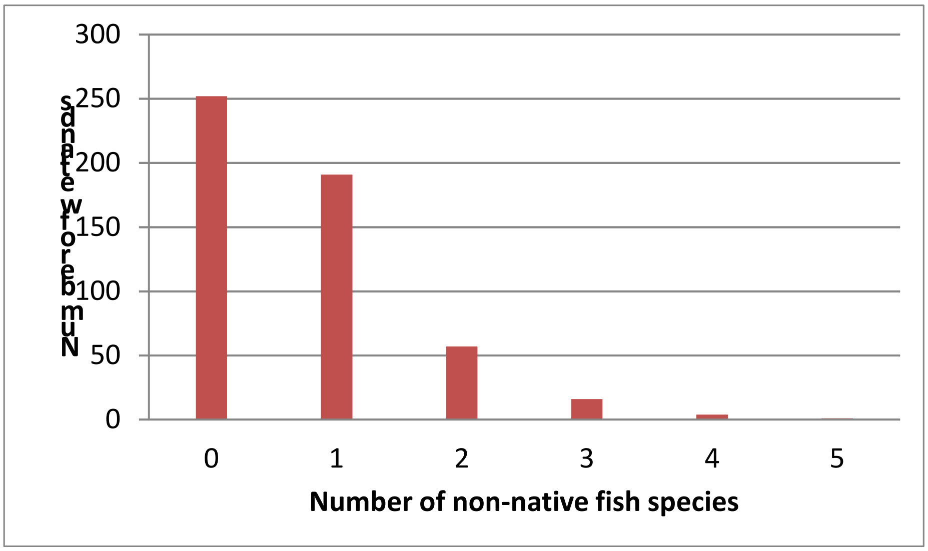

Figure 6. Number of Great Lakes coastal wetlands containing non-native fish species. Data from 2011 through 2015.

Total fish species did not differ greatly by lake, averaging 12-14 species per wetland (Table 9). 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, 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 9. 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 10), 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 10 and 11). 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 10). 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 10. 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. We are also noticing an effect of the benchmark sites in these summaries. We are finding 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 11). 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 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 is 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 11. 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 2014.

		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 7 and 8 for the faucet snail, *Bithynia tentaculata*. Figure 7 shows the range portrayed on the USGS website for this snail before we reported our findings. Figure 8 shows the locations where our crew found this snail. Finally, Figure 9 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.

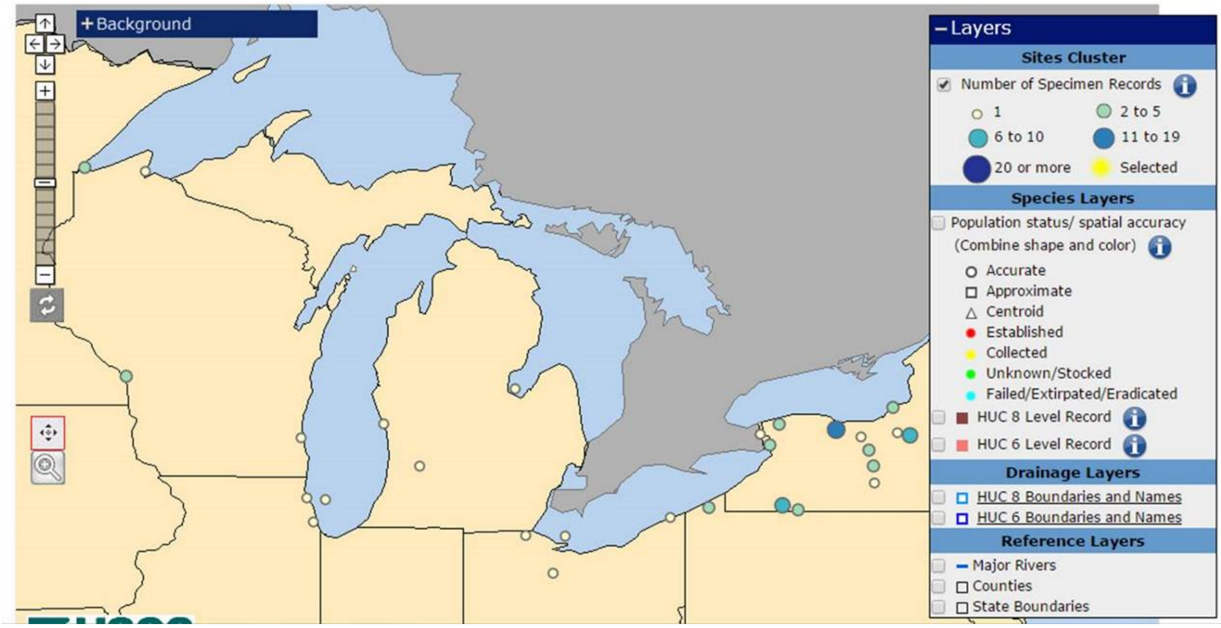

Figure 7. Locations of *Bithynia tentaculata* in USGS NAS website PRIOR to our project providing additional locations where they were collected.

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).

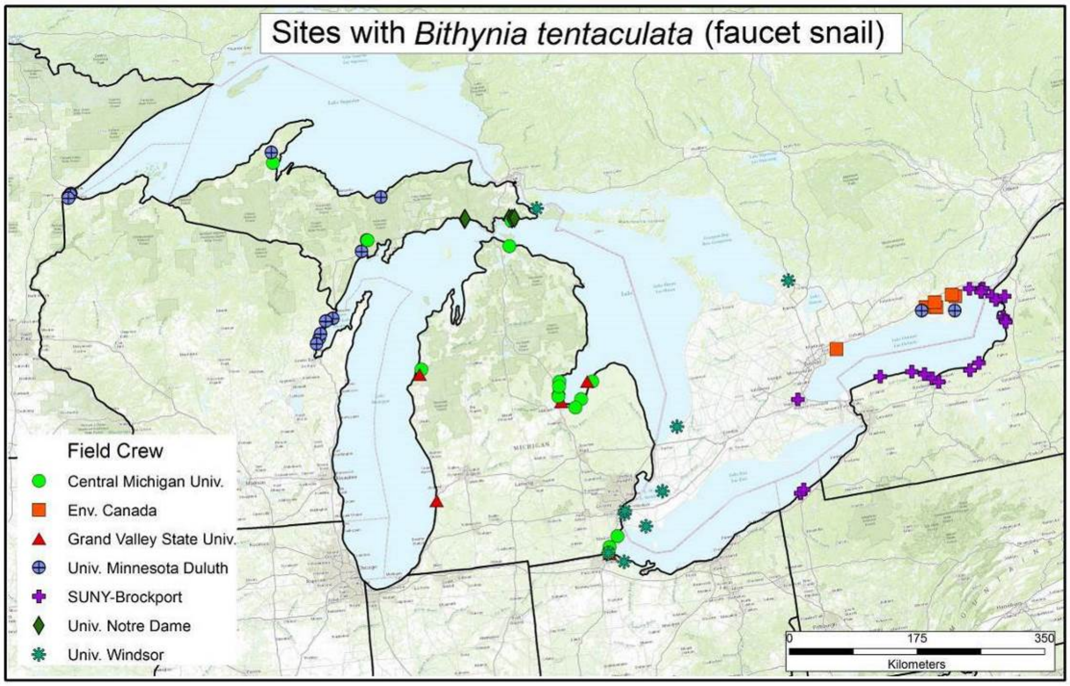

Figure 8. Locations of *Bithynia tentaculata* found by CWM crews, 2011 - 2013.

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.

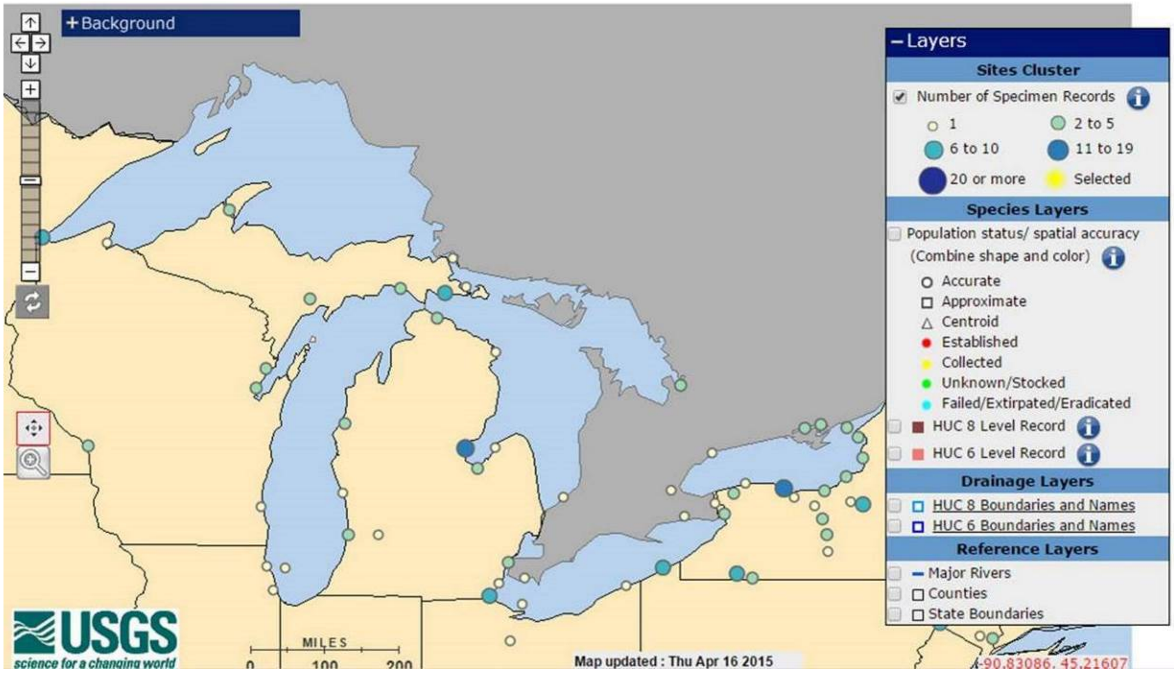

Figure 9. Locations of *Bithynia tentaculata* in USGS NAS website AFTER our project provided additional locations where they were collected; compare to Figure 7.

On average, there were approximately 45 wetland plant (macrophyte) species per wetland (Table 12), 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 12). 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 12. 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 currently have 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 12. 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 do 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 13). 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 is the only lake with no sampled wetlands being free of non-native species.

Table 13. 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 10). 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 still be missing small patches of invasives in some wetlands.

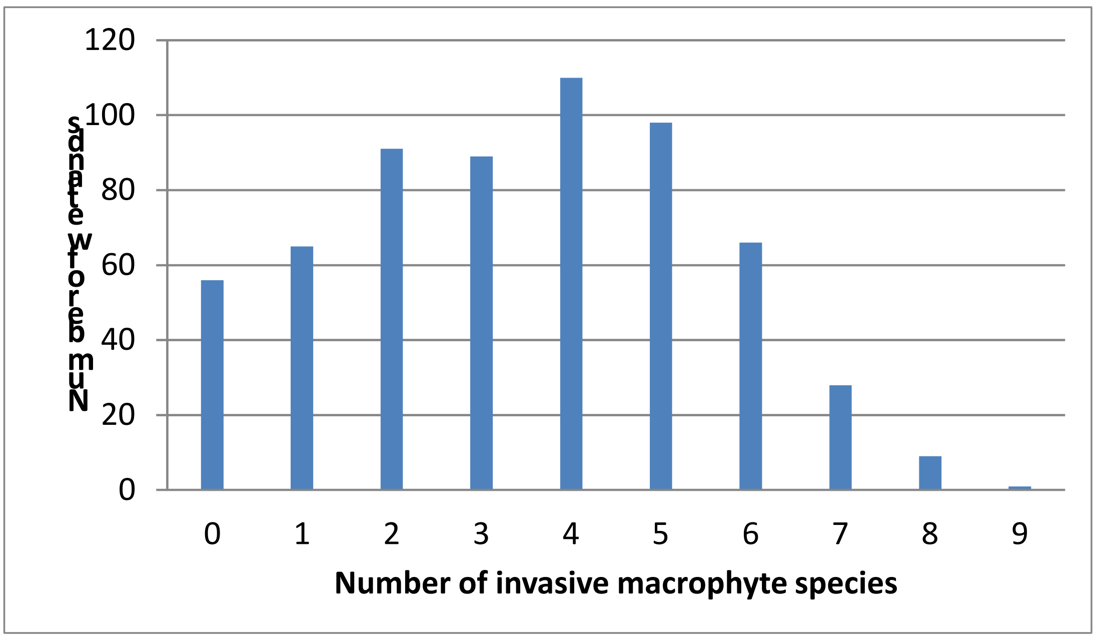

Figure 10. Number of Great Lakes coastal wetlands containing invasive plant species based on 2011 through 2015 data.

As an example for the state of Michigan, we also looked at wetlands with both invasive plants and plant species considered “at risk” (Figure 11). 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.

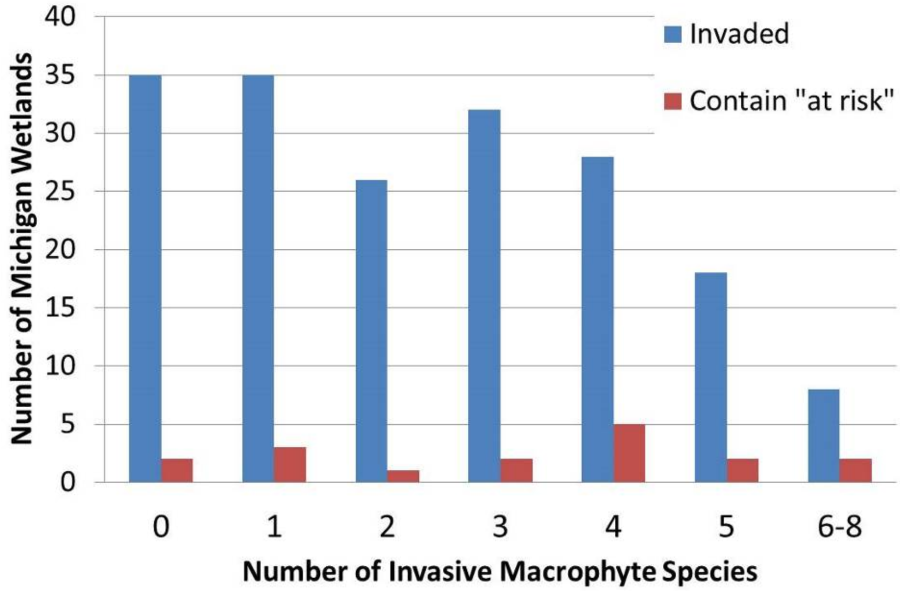

Figure 11. Number of state of Michigan Great Lakes coastal wetlands containing both invasive plant species and “at risk” plant species, based on 2011 through 2014 data.

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 12). Unfortunately, this shows that most sites have some level of invasion, even on Isle Royale. However, the more remote areas clearly have fewer invasives than the more populated areas and areas with relatively intense human use.

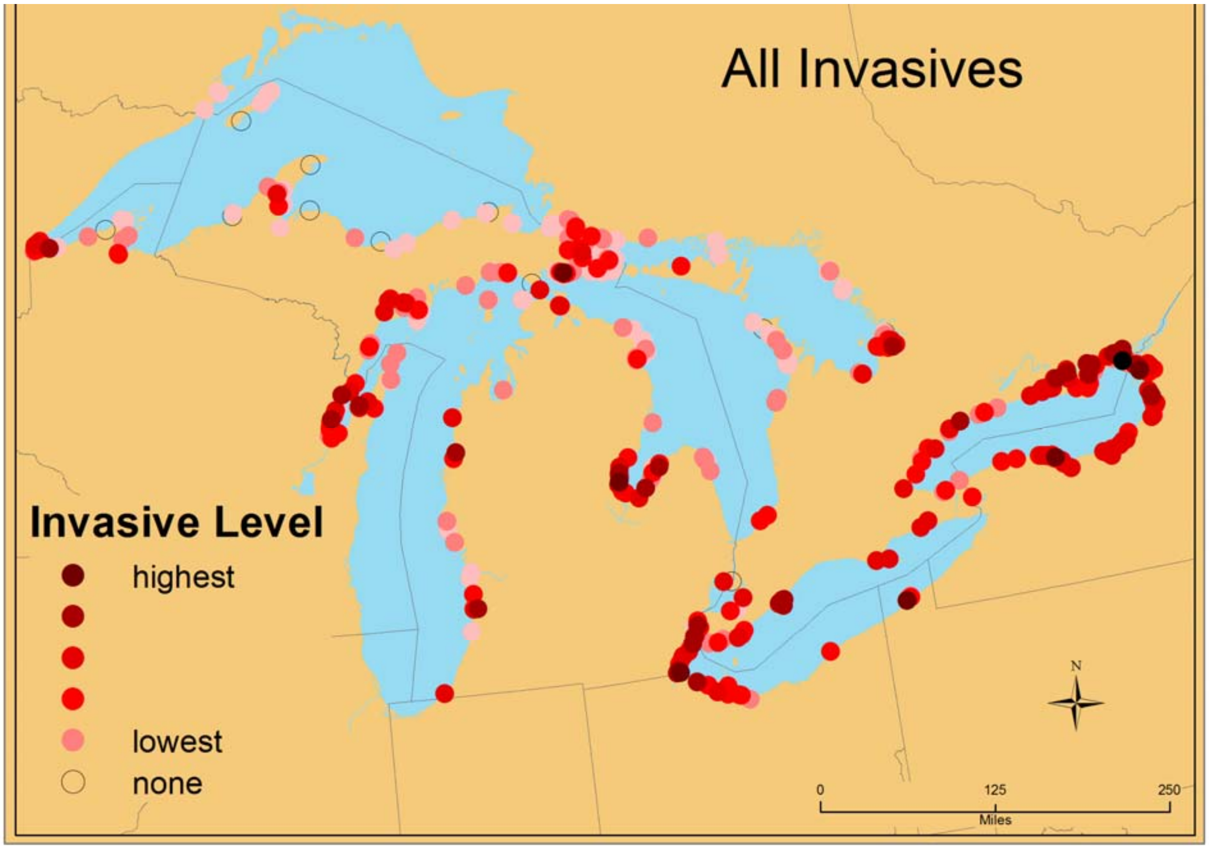

Figure 12. Level of “invadedness” of Great Lakes coastal wetlands for all non-native taxa combined across all taxonomic groups, based on data from 2011-2014.

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 Conservatizm (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.

The map (Figure 13, updated and revised for this report) 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

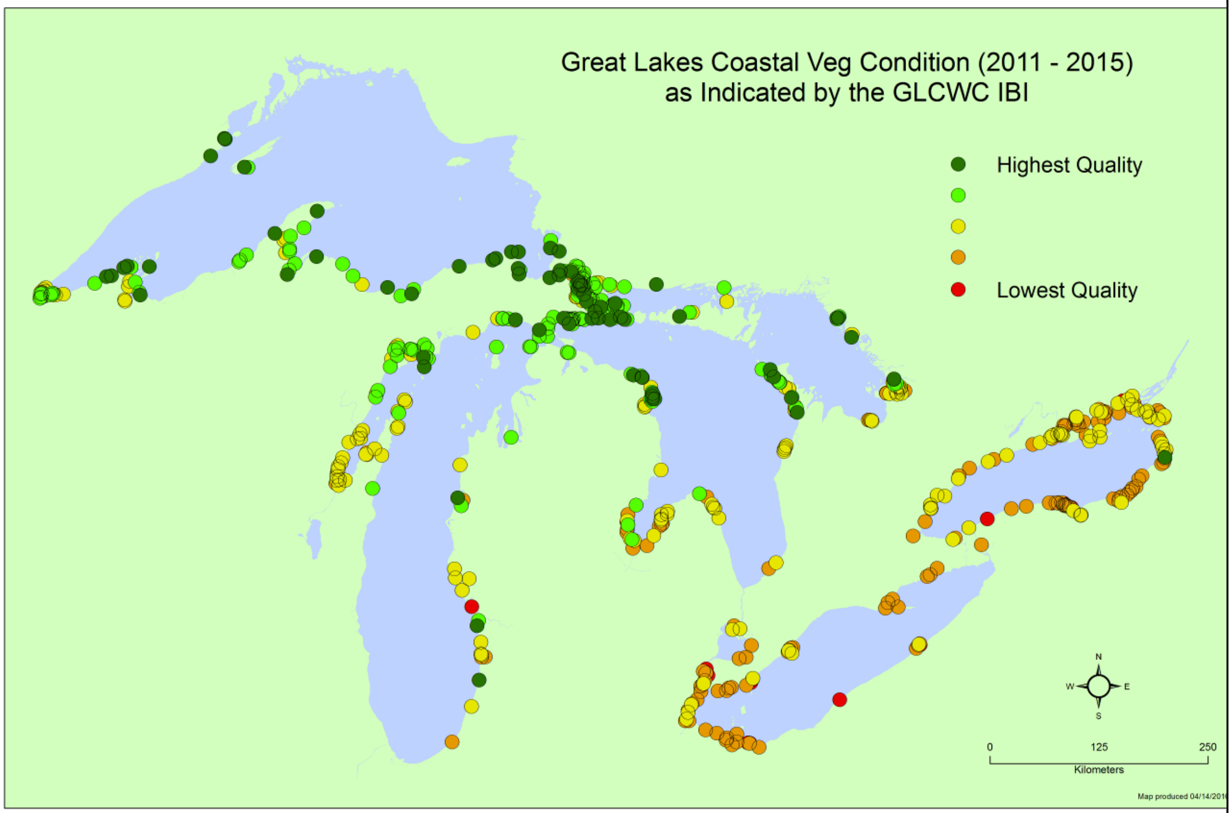

Figure 13. Condition of coastal wetland vegetation at sites across the Great Lakes. Circle color indicates vegetation community quality. The indicator is labeled “draft” while this indicator is investigated for robustness against varying water levels and latitude. Based on data from 2011 through 2015.

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 2011 through 2014 sites that contain these habitat zones (Figure 14, updated and revise for this report). Minor adjustment of metrics is continuing, so maps are not directly comparable across reports.

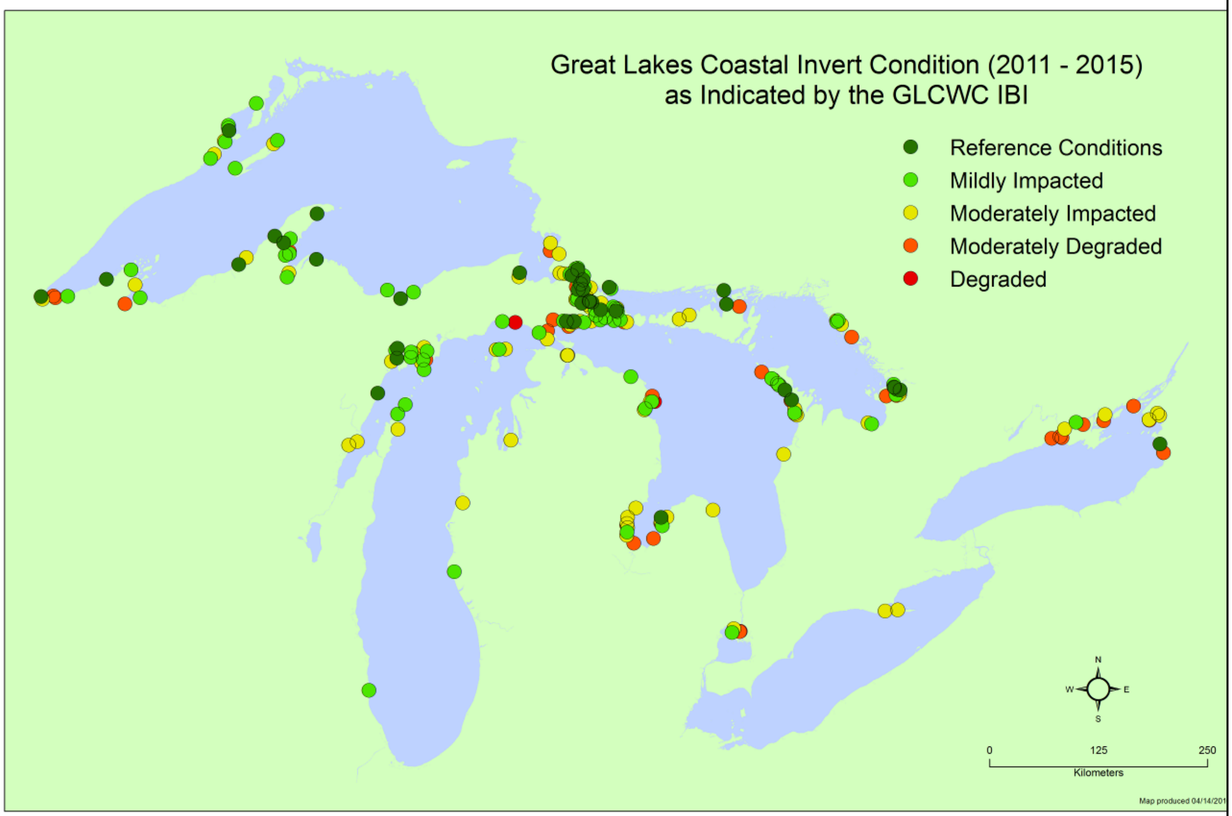

Figure 14. Condition of coastal wetland macroinvertebrate communties at sites with bulrush or wet meadow zones. The indicator is labeled “draft” while more zone IBIs are calculated. Based on data from 2011 through 2015.

The lack of sites on lakes Erie and Ontario and southern Lake Michigan is due to either a lack of wetlands (southern Lake Michigan) 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 reviewed 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 15). 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.

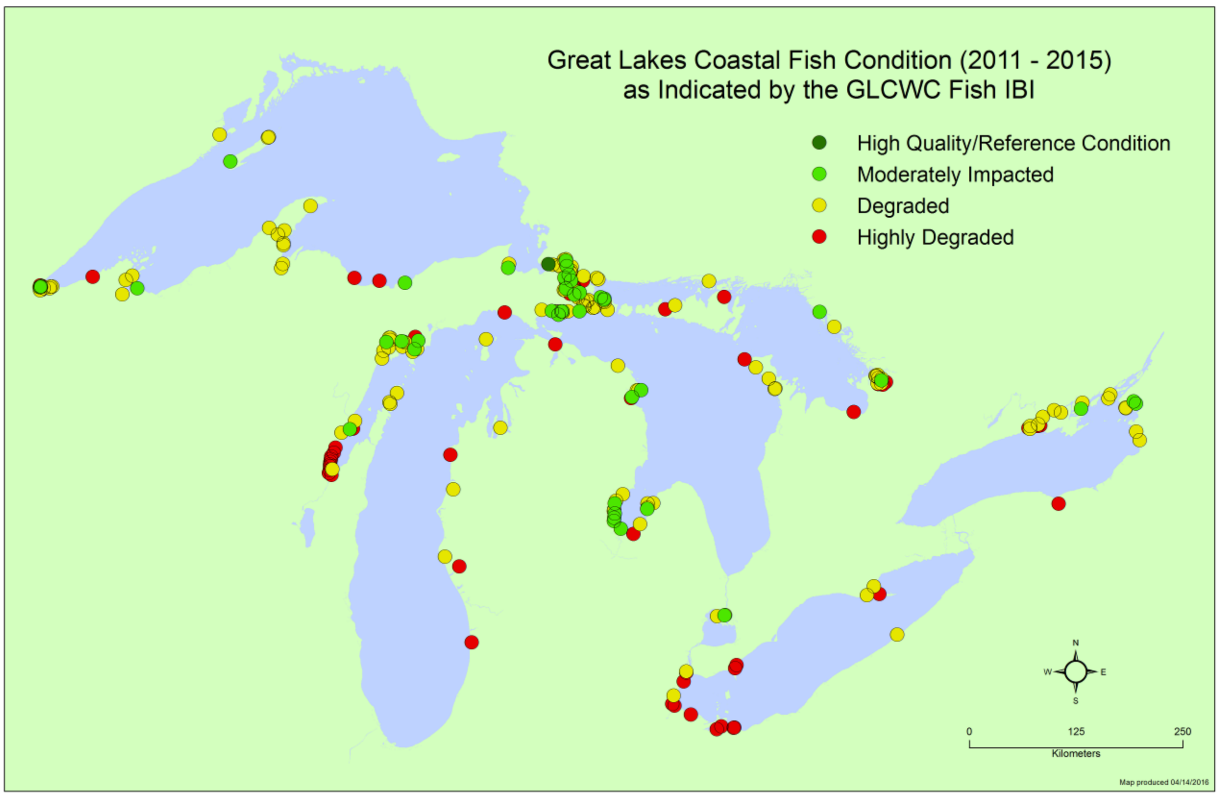

Figure 15. Condition of coastal wetland fish communties at sites with bulrush or cattail zones. The indicator is labeled "draft" while more zone IBIs are developed. Based on data from 2011 through 2015.

Fish PIs 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 and test the IBIs. 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.

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 has now been calculated for Great Lakes coastal (Figure 16). 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.

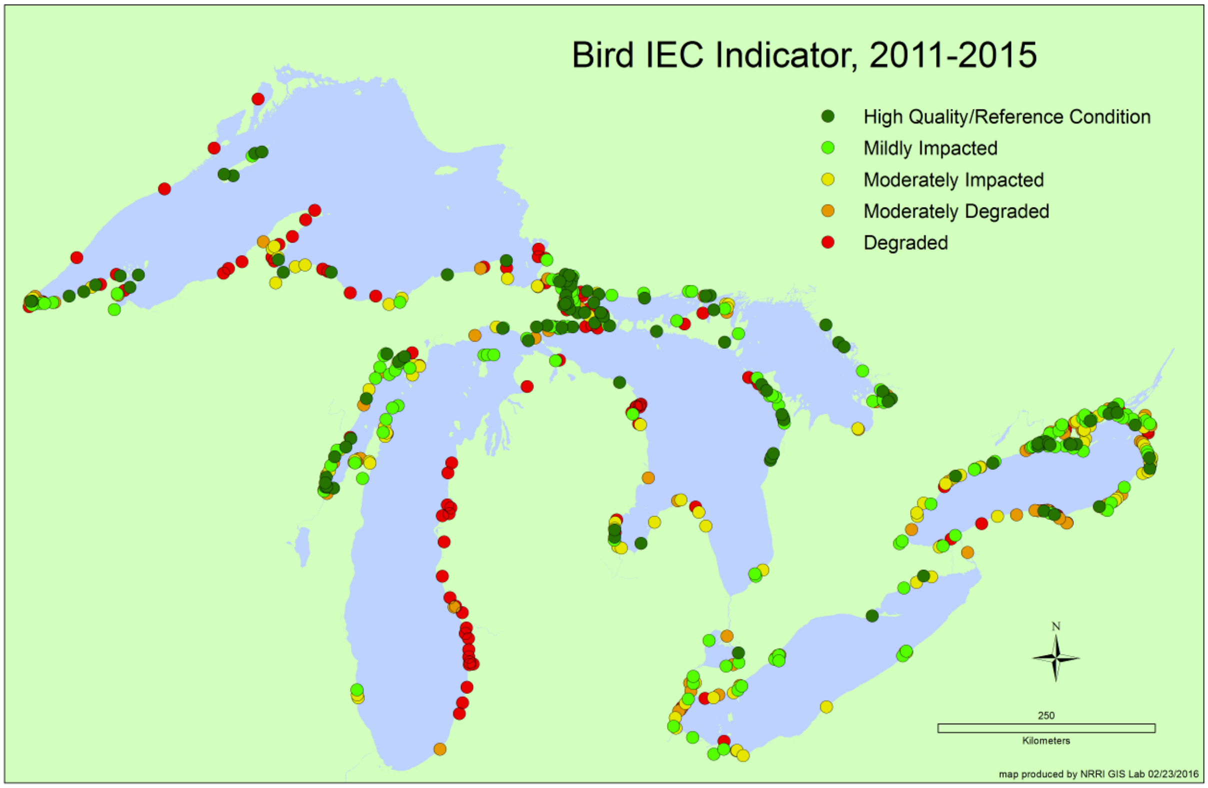

Figure 16. Condition of coastal wetland bird communties. This indicator is based on the IEC method. Based on data from 2011 through 2015.

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 17). 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. We may have to do some adjustments 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.

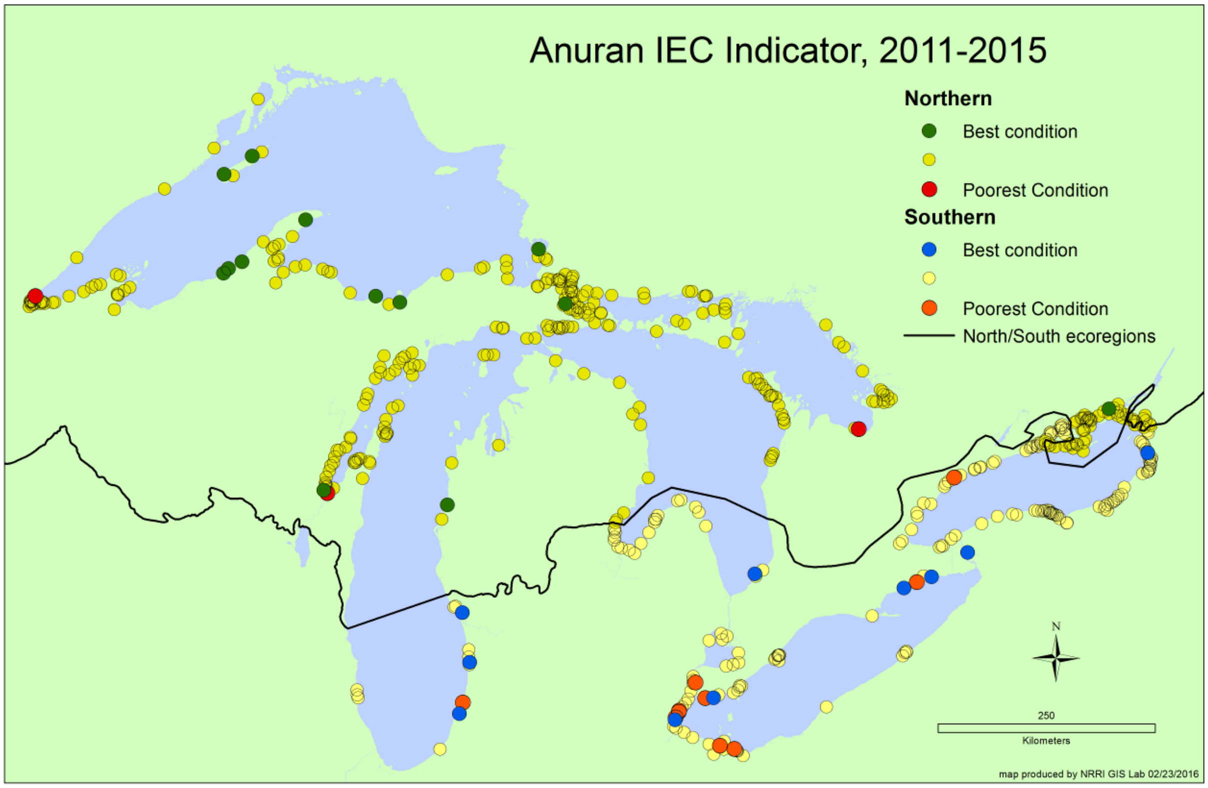

Figure 17. Condition of coastal wetland calling amphibian communities. This indicator is based on the IEC method, and it works best when shown separately for the northern and southern areas of the Great Lakes because of the differences in the amount of agriculture and developed land between these two 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 18). 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 in different plant morphotype zones (inset a). In addition, the indicator may change over time, as indicated in Figure 18 inset b.

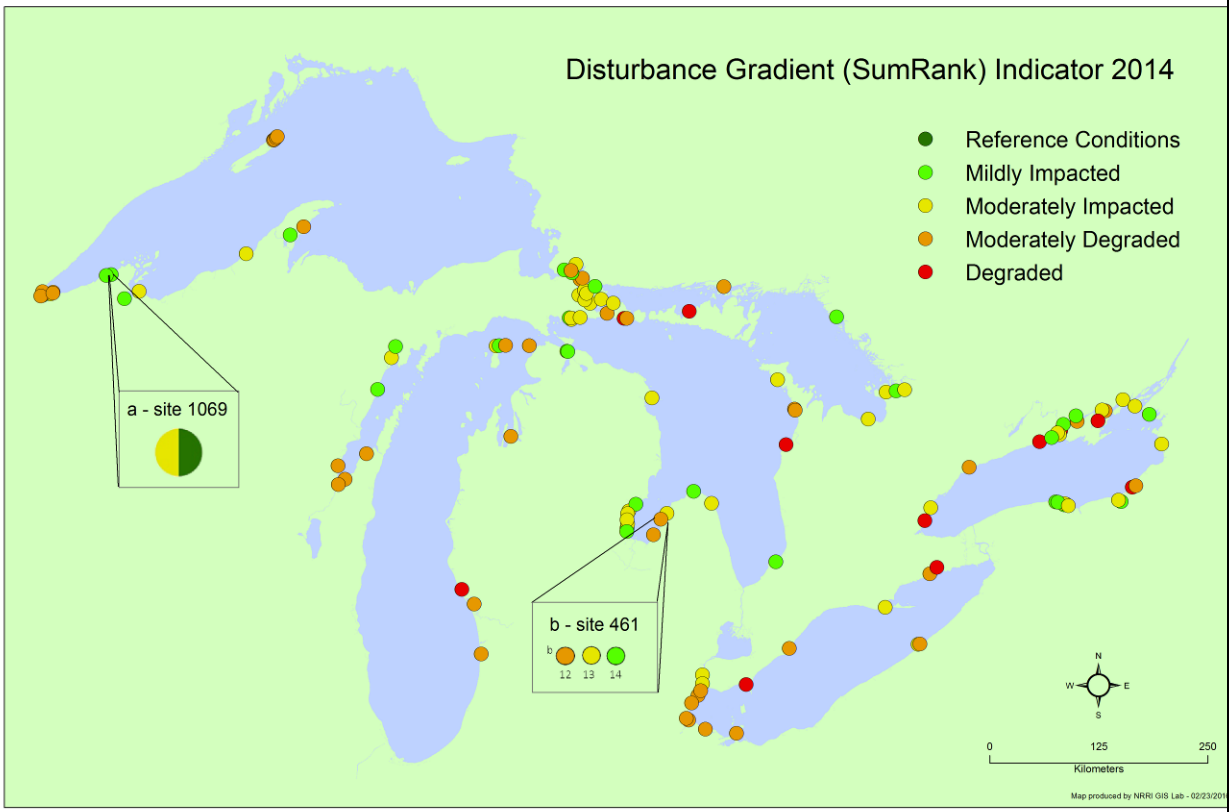

Figure 18. Draft disturbance gradient (SumRank) indicator. This indicator is based on landscape stressor data, site-based stressor data, and site water quality data. This example is based on data from 2014. Wetlands can have different scores for each plant morphotype within them (a), and the indicator 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 19). The website has been redeveloped and upgraded by LimnoTech, Inc., and transitioned from an NRRI server to a permanent web-hosting environment at Central Michigan University.

Figure 19. Front page of the re-created 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 20; 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.

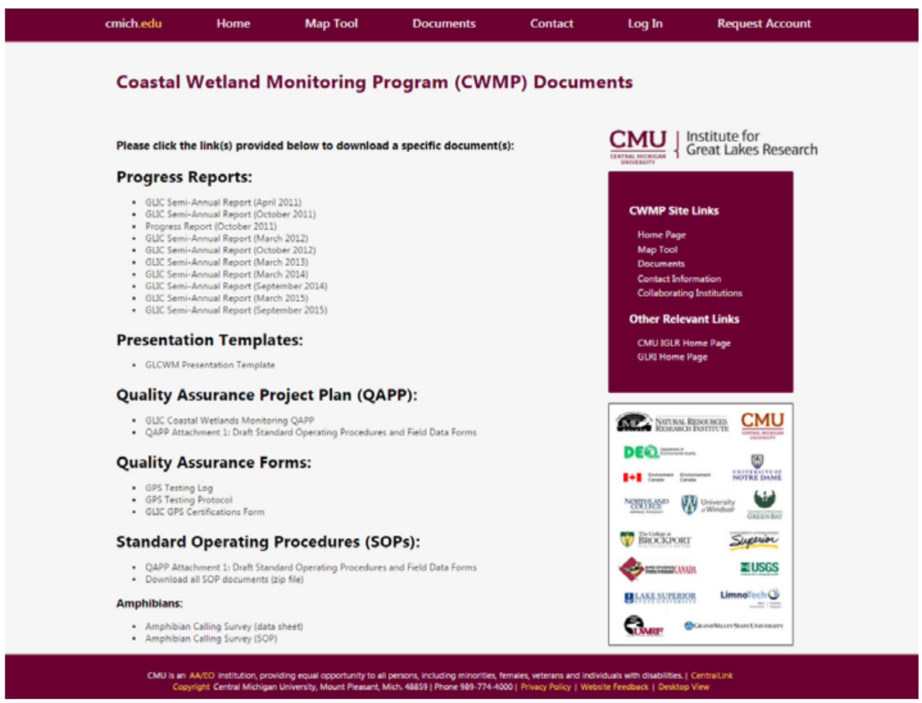

Figure 20. The Documents Download webpage.

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 21):

- 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 21), or 2) year sampled (Figure 22); and
- Reporting of basic site attributes (site name, geomorphic type, latitude, longitude, and sampling years).

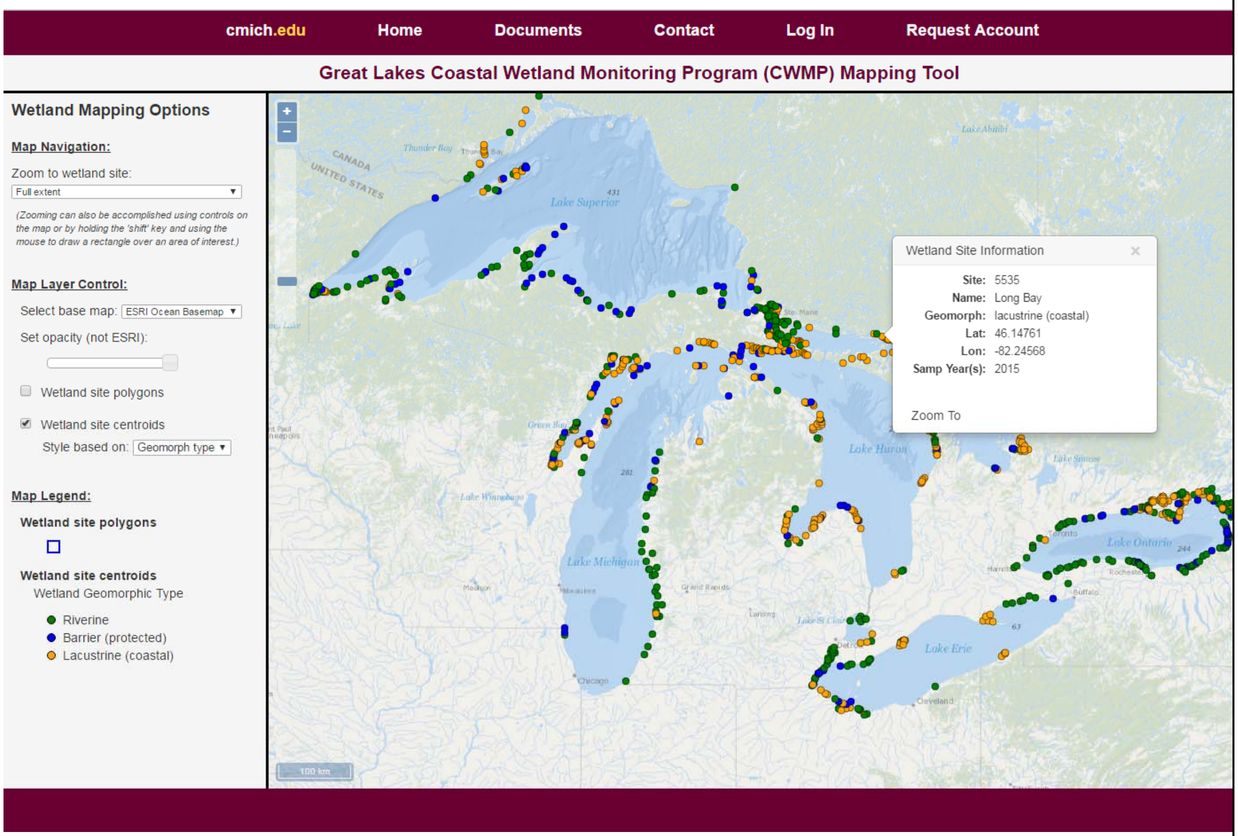

Figure 21. Mapping Tool webpage. Sites are color-coded by wetland type (protected, riverine, or open coastal). Only sites that have been sampled are shown.

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. (IBI scores for amphibians and birds will be incorporated into the site once available.)

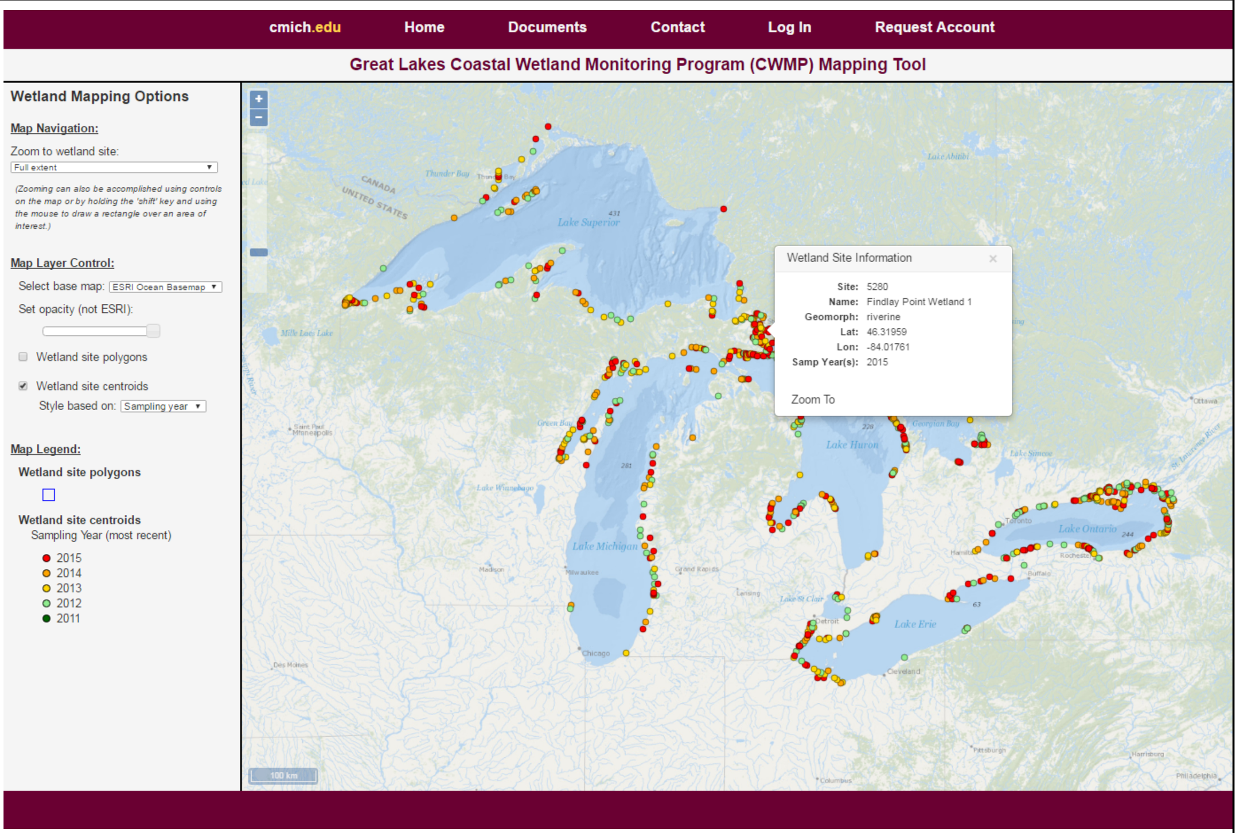

Figure 22. Mapping Tool webpage. Sites are color-coded by year sampled.

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 23). In addition, the actual IBI scores can be viewed by clicking on an individual wetland centroid.

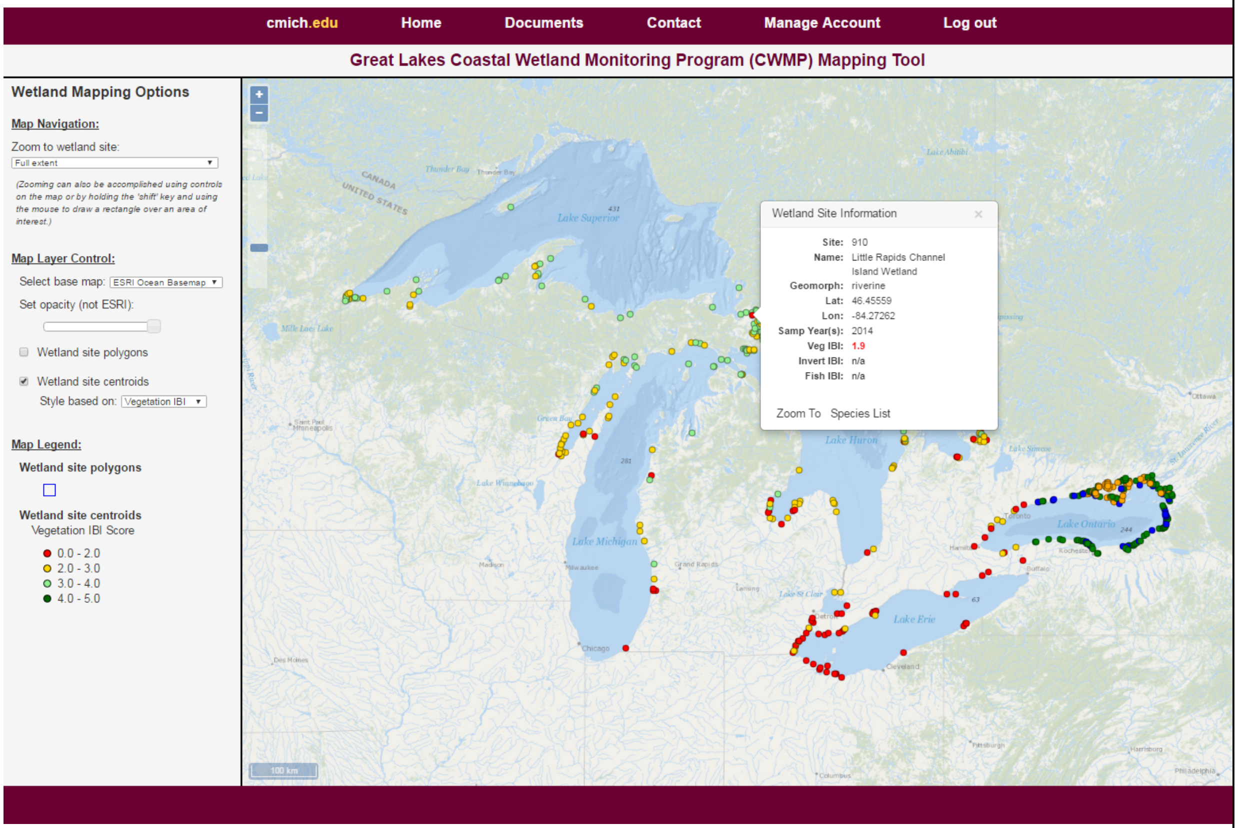

Figure 23. Coastal Wetland Mapping Tool with IBI scores displayed.

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 24), and the information can then be viewed and copied and pasted to another document, if desired.

Website Deployment and Next Steps

The official launch of the new CWMP website is occurring during the last week of April 2016, including the public components of the website and data management tools for CWMP principal investigators and collaborators. Once “live”, candidate users, including coastal managers and agency personnel, will be able to submit a request for an account on the website. The CWMP site administrators will 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 will create new user accounts that will provide access to raw data management tools. LimnoTech will be providing ongoing maintenance and support for the website over the next program year, and will modify and enhance the site as required to meet CWMP needs, as well as other end user needs.

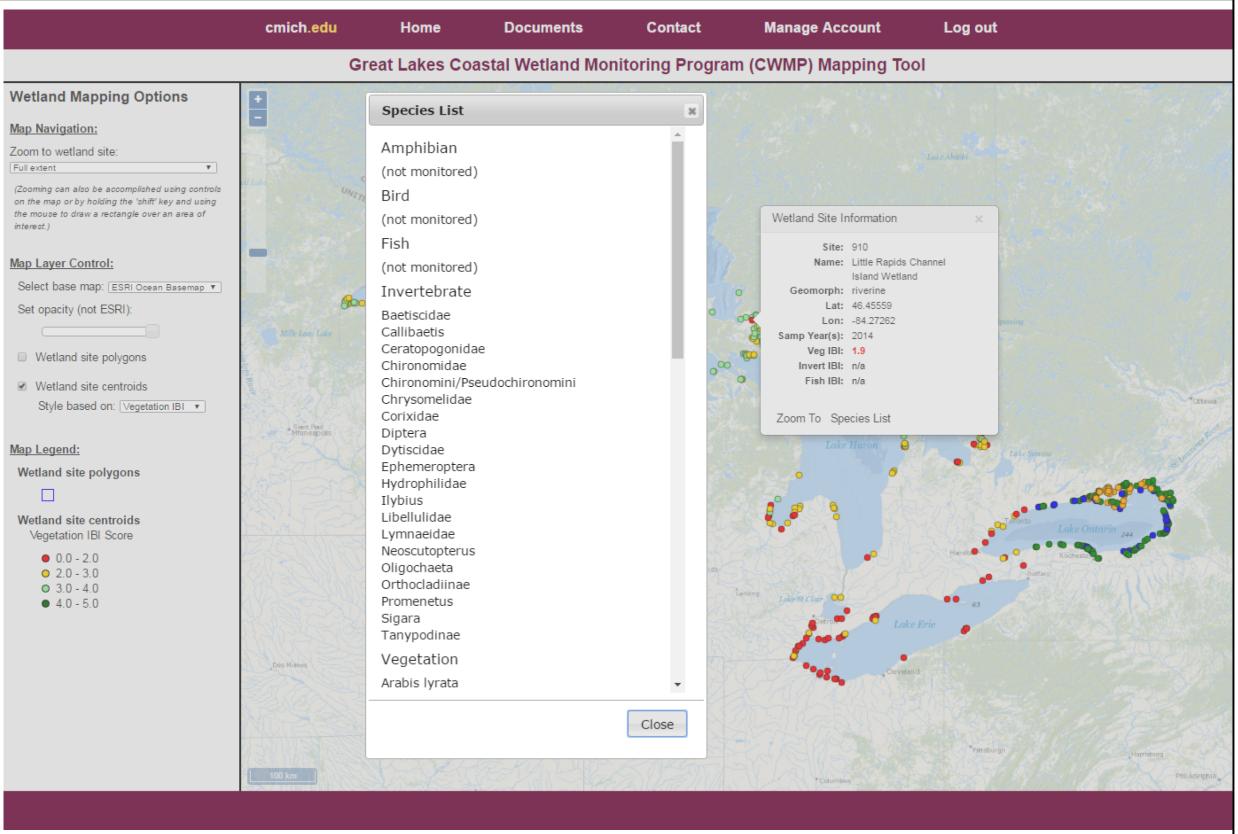

Figure 24. Coastal Wetland Mapping Tool with IBI scores and species list displayed.

TEAM REPORTS

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

2015 Sample Processing, Data Entry, and QC

All 2015 bird, amphibian, fish, habitat, and field and lab water quality data have been entered into the database and QC'd. Blinded macroinvertebrate samples were exchanged between NRRI and Lake Superior State University for identification QC. Vegetation data were subject to QA/QC procedures by visually checking every piece of entered data in the data management system against the field sheets. Errors were corrected in the database and noted on field sheets. Error rates remain very low, <1% of all data entries. Approximately 20 unknown specimens from northern Lake Michigan and western Lake Superior wetlands were identified through herbarium work with the help of regional experts and updated in the database.

Birds and Amphibians:
All field observers for the western Great Lakes team are returning field observers. They will still be expected to attend the annual training, review the QAPP and SOPs, but all will have completed the online certification requirements (see above). The supervising PI will conduct mid-season checks by visiting survey locations and verifying that proper protocol is being implemented. All data entry and QA for bird and amphibian records will be completed (100%) by September 2016.

Metrics and Indicator Calculations

Birds and amphibians:
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. 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 determined how these characteristics influenced their distribution and abundance. 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 wetlands, 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 identified characteristics of the Great Lakes coastal wetlands 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 (Table 14) within the Great Lakes wetlands.

Table 14. List of species considered to be either wetland obligate species (bold) or indicators of wetland condition.

Common name	**Scientific Name**	**Common name**	**Scientific Name**
Canada Goose	*Branta canadensis*	European Starling	*Sturnus vulgaris*
Mallard	***Anas platyrhynchos***	Northern Cardinal	*Cardinalis cardinalis*
Pied-billed Grebe	***Podilymbus podiceps***	**Sedge Wren**	***Cistothorus platensis***
American Bittern	***Botaurus lentiginosus***	American Goldfinch	*Carduelis tristis*
Least Bittern	***Ixobrychus exilis***	Mourning Dove	*Zenaida macroura*
Virginia Rail	***Rallus limicola***	**Alder Flycatcher**	***Empidonax alnorum***
Sora	***Porzana carolina***	Gray Catbird	*Dumetella carolinensis*
Common Moorhen		Bobolink	*Dolichonyx oryzivorus*
Sandhill Crane	***Grus canadensis***	Baltimore Oriole	*Icterus galbula*
Black Tern	***Chlidonias niger***	American Redstart	*Setophaga ruticilla*
Willow Flycatcher	***Empidonax traillii***	Bald Eagle	*Haliaeetus leucocephalus*
Marsh Wren	***Cistothorus palustris***	Northern Harrier	*Circus cyaneus*
Common Yellowthroat	***Geothlypis trichas***	Brown-headed Cowbird	*Molothrus ater*
Swamp Sparrow	***Melospiza georgiana***	Brown Thrasher	*Toxostoma rufum*
Red-winged Blackbird	***Agelaius phoeniceus***	White-throated Sparrow	*Zonotrichia albicollis*
Yellow-headed Blackbird	***Xanthocephalus xanthocephalus***	Killdeer	*Charadrius vociferus*
Common Grackle	*Quiscalus quiscula*	**American Coot**	***Fulica americana***
American Robin	*Turdus migratorius*		

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). Data that has been entered into the data management system and undergone quality control checks (2011-2015) were used to calculate some of the metrics and indicators for these wetlands. Bird and amphibian indices of ecological condition (IEC) have been calculated for the Great Lakes coastal wetlands following the methods of Howe et al.

(2007a,b) modified by Gnass Giese et al. (2015). These indices were developed for Great Lakes coastal wetland bird and amphibian communities from data collected from Bird Studies Canada's Marsh Monitoring Program (MMP), and calculations were completed in December 2015. Results from these analyses were made available in a draft for the upcoming State of the Great Lakes 2017 report to SOLEC (Tozer et al. 2015). This report describes the condition of the Great Lakes coastal wetlands based on the relative abundance of wetland breeding birds and the presence of breeding anurans frogs (anurans). A mean IEC was calculated for over 1,500 wetlands surveyed throughout the Great Lakes Basin.

Aquatic macrophytes:
Previous indicator work: PIs on the vegetation project have been working to analyze temporal patterns in floristic quality metrics (e.g. mean Coefficient of Conservatism, FQI). We have been investigating how much these metrics change from year to year in typical situations and in other cases where water level changes or human influences have been substantial through time. Throughout 2015, N. Danz has undertaken statistical analysis of the entire CWM vegetation dataset to assist the development of SOLEC plant community indicators. In addition, several hundred CWM point vegetation surveys from the St. Louis River estuary have been combined with data from a variety of other studies to develop a database with >5000 vegetation surveys. These data are being used to characterize plant condition throughout the estuary, identify reference sites, and measure the success of restoration activities.

Update: In Fall/Winter 2015, PIs on the vegetation project have been working to analyze temporal patterns in floristic quality metrics (e.g. mean Coefficient of Conservatism, FQI). We have found scores of two vegetation indices, Mean C and wC, to reflect stress, to vary predictably with respect to spatial and geomorphic factors, to have low levels of inter-annual variability, and to be insensitive to natural inter-annual variability in plant community composition. Further work at indicator development with these metrics is ongoing.

Leveraged benefits

Conservation Assessment for Amphibians and Birds of the Great Lakes: Several members of the project team have initiated an effort to examine the role that Great Lakes wetlands play in the conservation of amphibians and birds in North America. The Great Lakes have many large, intact freshwater wetlands in the interior portion of the North American continent. Their unique character, size, and plant composition supports populations of many species of amphibians and birds; many of which have been identified as endangered, threatened, or special concern in North America. The participants will use 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 as critical input to this assessment.

Comprehensive estuary aquatic vegetation database: Vegetation data from surveys in the St. Louis River Estuary have been incorporated with other datasets from the region to more fully characterize floristic condition throughout the estuary and AOC. This work is assisting the evaluation of restoration efforts.

Benchmark sites: Two sites within the Menominee River harbor area of Marinette, WI were sampled by special request from the Wisconsin Department of Natural Resources. These data are not entered into the CWM database because the sites (7067 and 7068) do not meet normal site selection criteria (site 7067 actually overlaps the Northern portion of CWM site 1704). The information gathered by NRRI field crews performing CWM methods will help WDNR resource managers assess environmental status as restoration progress is made. The area surrounding the two sites is a riverine port and ship yard. Portions of the harbor have arsenic impacted sediments and restoration efforts have been completed in some areas and are ongoing or planned for others. NRRI field technicians found fish taxa common to other wetlands in the area, but observed an uncommonly-high density of large bryozoan colonies in the two wetlands visited (Figure 25).

Figure 25. NRRI field technician Nick Winter holding a bryozoan colony attached to a cattail stalk, and Jon Utecht setting fyke net (background) at site 7067. Large bryozoan colonies were common at site 7067 and neighboring site 7068.

NRRI continues to work with WDNR and The Nature Conservancy (TNC) to collect and provide data on site 1697 (BENCHMARK: Suamico River Area Wetland). Both entities are both involved in the restoration activities of this wetland within Green Bay. In 2011 NRRI sampled outside a diked area following CWM methods, and in 2013 we sampled within the diked area as a special request. In 2015 the NRRI field crew sampled 1697 outside the diked area again, and in a newly created habitat called the “pike fingers” (Figure 26). The “pike finger” construction was performed in 2013 and was designed to provide shallow wetland habitat for spawning fish, particularly pike and muskellunge. In 2015 NRRI technicians observed abundant vegetative growth and detected young-of-year largemouth bass, yellow perch, and bowfin. Several other juvenile and adult fish species were captured, including northern pike.

Figure 26. NRRI sampled the newly-created “pike fingers” of site 1697 by special request from WDNR and TNC. Numbers are sample replicate locations.

NRRI collected 62 tissue samples from black and brown bullhead throughout the entire NRRI region, and 10 tissue samples from suspected longnose X shortnose gar hybrids from just the Green Bay area. Tissue collection of specific species is part of a CWM spin-off project to detect hybridization of closely related species, and we hope to secure future funding to conduct the genetic analysis. NRRI field staff collected 160 invertebrate samples in 2015, which are still being identified. All water quality data from the NRRI analytical lab was QC'd and entered into the database back in October/November, 2015.

Site 1064 was accessed and sampled with special permission from the Red Cliff Band of Lake Superior Chippewa, and we received permission from the Bad River Band to sample site 1035. They also wait patiently for the public website to become available so they can see how IBI scores of their wetlands sampled by the NRRI team over the last several years compare to other wetlands sampled by the CWM project.

The vegetation survey crew particularly noticed the effects of beach grooming on wetlands along the shores of northwestern Lake Michigan within the borders of the state of Michigan, which allows this activity. Unfortunately, the higher water levels have not stopped some property owners from continuing to attempt to manage wetland vegetation, even though it is now in the water and should now be protected by law. Crews noticed property owners using heavy machinery to attempt to channelize and drain vegetated areas that were likely dry in the previous years.

Field Training

Birds and Amphibians:
Training for amphibian surveys will be held on 28 March 2016 and bird crew training will take place 24 – 26 May 2016. Training involves instructing crews on how to conduct standardized field surveys, on basic travel procedures, and on appropriate field safety measures. Individuals are trained to proficiently complete field sheets and audio testing is also completed to insure that their hearing is within the normal range. Rules for site verification, safety issues including caution regarding insects (e.g., Lyme's disease), GPS and compass use, and record keeping are also included in field training to insure that the guidelines in the QAPP are being followed. All individuals involved in conducting the surveys in 2016 have taken and passed each of the following tests on 1) amphibian calls, 2) bird vocalization, and 3) bird visual identification that are based on an on-line system established at the University of Wisconsin, Green Bay, prior to conducting surveys – see http://www.birdercertification.org/GreatLakesCoastal. All individuals who participated in sampling in 2015 passed the required tests prior to sampling. Individuals planning to conduct surveys in 2016 for either birds or amphibians must have taken and passed the necessary test (s) by the following dates: 1) Sunday, 20 March 2016 for amphibian surveys, and 2) Sunday, 15 May 2016 for bird surveys. Field observers who have become certified in previous years are not required to become certified again in future years.

All new and returning field observers will review the QAPP and SOPs and complete the online certification requirements (see above) prior to conducting field surveys. The supervising PI will conduct mid-season checks by visiting survey locations and verifying that proper protocol is being implemented.

Fish, Macroinvertebrates, Vegetation, and Water Quality:
Fish, macroinvertebrate, vegetation, and water quality sampling training will be held in Duluth, Minnesota, and Superior, Wisconsin, in mid-June 2016 and will continue in Green Bay, Wisconsin at the end of June/early July. We will be adding a couple of new fish/invertebrate/water quality crew members to our crew members returning from last year. The returning crew members will help train the newer crew. The vegetation crew has three returning crew members, and so will also have a very experienced crew this summer. All field technicians will be trained in and tested on all standard procedures, including a field-based fish or vegetation identification exam (depending on the crew). Training includes how to determine if a site meets project criteria, all aspects of sampling the site, proper recording of data on datasheets, GPS use and uploading, water quality sample collection and meter calibration (fish/invert crew only), as well as sample processing. Much of the training takes place in the field at a typical coastal site to ensure field members learn (or review) appropriate techniques. Safety training covered aspects of field safety including safe boating; protection against the elements, animals, insects, and plants; and what to do when things go wrong. A CPR/AED and first aid review class will also be offered to fish/invert crew members.

We have received our University of Minnesota Institutional Animal Care and Use Committee permit for fish sampling. We are in the process of obtaining all appropriate sampling permits from the various state agencies and property owners.

Site selection

Birds and Amphibians:
In 2016, a total of 49 sites have been selected to be surveyed by the western regional team for birds and amphibians. Of these sites, 4 sites have been sampled in a previous year and are being revisited, 2 sites that are scheduled to be sampled this year will also be resampled in 2017, all other sites (n=34) are sites previously sampled (2011-2015), and 9 are benchmark sites selected because they are of particular interest for restoration potential. Many of the benchmark sites are located in the St. Louis River Estuary and are in some stage of planning for restoration work. Restoration activities for the sites are being coordinated by the Minnesota Pollution Control Agency and the US Fish and Wildlife Service, with many collaborators from multiple agencies and university research groups.

All of the 49 sites selected in 2016 were sites that were previously selected and sampled by at least one of the taxonomic groups during the first round of CWM sampling (2011-2015). Of the 49 sites selected, nine were previously rejected by the bird and amphibian team because they were deemed unsafe or inaccessible to field crews and therefore will be excluded from sampling in 2016.

The 40 sites that will be visited and sampled by bird and amphibian field crews stretch from the Duluth-Superior harbor area both northeast along the shore of Lake Superior and eastward along the south shore of Lake Superior to the eastern end of the Upper Peninsula of Michigan and into Northeast Lake Huron. In 2016, several island sites are also scheduled to be sampled, including 11 sites in Wisconsin (Madeline Island: site 1046), and 10 wetland sites in the Apostle Islands National Lakeshore, which were requested to be surveyed by the National Park Service. The Apostle Island sites (Sand Island, Sand River, Little Sand Bay, Devils Island, Outer Island, Stockton Island (2 sites), Michigan Island, and Long Island (2 sites), are being sampled in addition to the 41 sites selected by our project protocol. The park service will provide us with boat service to access the sites.

Fish, Macroinvertebrates, Vegetation and Water Quality:
The Bad River Band made a formal requested that CWM site 1046 on Madeline Island (the largest of the Apostle Islands) be sampled, because they have limited data from that area of their Tribal land. In 2016 the NRRI crew will visit site 1046, along with 24 other wetlands. Fifteen of the wetlands are riverine, five are barrier protected, and five are lacustrine (coastal). We have again picked up several sites from the Central Basin Team to assist them with all of their sites, although we did trade one site to them because it is much closer for their crews. Nine of the wetlands are listed as BENCHMARK and are either in areas of restoration interest or are actively monitoring post-restoration changes (such as site 1697: BENCHMARK: Suamico River Area Wetland). Requests for sample permits will begin soon, as well as coordinating the project training for staff working in the field this summer.

Field sampling plans

Birds and Amphibians:
Each of the 40 coastal wetland sites will be visited a total of four times between 1 April and 15 July 2016. Amphibians will be sampled three times at dusk during this period and birds will be surveyed twice, once in the morning and once in the evening. The additional sites scheduled to be surveyed in the Apostle Islands will be visited twice during the breeding season for birds only. Sampling remote island sites is too dangerous for water travel at night.

Fish, Macroinvertebrates, and Vegetation:
NRRI crews will be sampling sites between the end of June and the end of August, starting in Green Bay and moving north and west following phenology.

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

Sample Processing and Data Entry (2015)

Central Michigan University:
100% of 2015 field data has been entered and checked by a second person. 100% of 2015 macroinvertebrate data has been identified, but QC is in progress. 100% of 2015 macroinvertebrate data has been entered, but is still pending changes after QC from GVSU. Invertebrate sample exchange with GVSU has been initiated and QC is expected to be complete in late April. 100% of vegetation data has been entered and QC is completed. All 2015 bird and amphibian field survey data has been uploaded and QC'd in the database.

Lake Superior State University:
Data entry for all parameters has been entered and 100% of the data have been checked following the QA/QC procedures. Sample exchange with NRRI for QA/QC is underway and QC is expected to be complete by the end of April. 100% of 2015 macroinvertebrate samples have been identified, but QC is still underway; 100% of macroinvertebrate data entry has been completed, but changes will be made if necessary after QC with NRRI.

Grand Valley State University:
All field data (i.e., fish, invertebrates, and water quality) was entered and checked for quality control. Identification of the macroinvertebrates collected during the 2015 field season was completed in February 2016 (and that data were entered and checked for quality control in February 2016). 100% of the 2015 field data has been entered; 100% has been checked by a second person. 100% completion of macroinvertebrate identification for samples collected during the 2015 field season; 100% of 2015 macroinvertebrate data has been entered, but is still pending changes after QC from CMU. We completed our annual IACUC and DNR Collectors Permit reports for fish sampling (for the 2015 field season), and Ruetz has applied for a scientific collector's permit to sample fish for the 2016 field season.

University of Notre Dame:
Analysis of 159 chlorophyll-*a* filter foil samples from CMU, GVSU, LSSU, UWN, CWS-ON (Env. CA) was completed during October-November 2015. We followed the same 90% Buffered Acetone extraction, with filters torn and centrifuged, then analyzed in the dark using a spectrophotometer. This methodology has been implemented since 2011 and no problems were encountered in 2015. Data was sent out to the respective labs for database entry and then checked by Co-PI/QA manager, Matt Cooper.

2015 Field Season Preparations

Site Selection

Central Michigan University received the 2016 fish/invertebrate/vegetation site list and distributed sites among the other central basin crews (University of Notre Dame, Grand Valley State University, and Lake Superior State University). In total, 57 sites were chosen for the central basin crews to sample, six of which were benchmark sites where ongoing restoration is taking (or scheduled to take) place. Of the 57 sites to be sampled in the summer of 2016, 18 were assigned to Central Michigan University, 9 were assigned to the University of Notre Dame, 8 were assigned to Grand Valley State University, and 9 were assigned to Lake Superior State University. Since this number of sites (57) exceeded the capacities the central basin crews, the University of Minnesota-Duluth offered to sample 9 sites located in the Green Bay and Keewenaw Peninsula regions, and the State University of New York-Brockport offered to sample 4 sites located in the western Lake Erie region.

Central Michigan University:
In January, a full-time temporary employee, Laura Moore, was hired on to help with data analysis and work as a technician on the summer field crew. Laura has previously worked on the CMU field sampling crew during her undergraduate career. CMU does not intend to hire any new technicians for the coming field season as a full crew of returning technicians is available. In addition, future vegetation surveys will be conducted for the Central basin crew with CMU as a base. William Van Wijnen is intended to lead vegetation surveys again this coming summer along with a new graduate student, Erica Fraley.

CMU Amphibian and Birds:
Bird/amphibian crew site selection for 2016 currently includes 47 wetland sites to sample for amphibians and birds. These sites are located Michigan and Ohio borders of Lakes Erie, Huron, and Michigan. Three teams, each with two members, will be used to complete surveys. Field crews will consist of undergraduate student technicians and graduate student crew leaders. Training for amphibian surveys was completed at CMU on 15 March 2016. Crew members have been tested and certified for identification of frog and toad calls and proper field procedures. Amphibian surveys will likely begin by mid-April 2016, dependent on temperature. Training for bird surveys, procedures, and certification of bird identification will occur in April 2016 prior to sampling.

Lake Superior State University:
In January, a full-time technician, Jonathan Edwards, was hired on to lead the summer field crew, complete invertebrate identification, and repair any data entry issues. Edwards and Moerke also attended the annual GLCWM meeting in Midland.

In February, summer technician hiring was initiated. Announcements were posted and interviews were conducted, and three technicians (Sam Day, Anna Bush, and Bryant Smak) were hired. Edwards and Day worked on the project in 2015, so they are familiar with sampling protocols, but the entire crew will receive training in the early summer to ensure their competency in all parts of the project.

Reporting to the MDNR for the scientific collector's permit was completed in March and we are awaiting the collector's permit for 2016 sampling.

Grand Valley State University:
Ruetz lab manager, Andrya Whitten, left GVSU for a position with USFWS. Graduate student, Travis Ellens, has taken over as 2016 field crew lead for the GVSU crew. Two undergraduates have been hired as technicians to assist with sampling in the 2016 field season. Travis Ellens attended the Feb. 19 planning meeting for the grant in Midland, Michigan.

The GVSU crew plans to visit the eight sites they were assigned for the 2016 field season. Sampling is planned for the weeks of Jul 25-29, August 1-5, and August 8-12. GVSU will continue to coordinate with the CMU crew for a potential training day in the field prior to the start of our 2016 fieldwork.

University of Notre Dame:
The UND crew will be visiting 9 sites, including 5 in the Lake Michigan basin (in IL, WI & MI) and 4 sites in Lake St. Clair (MI). The UND crew will be trained by the NRRI – Brady group in late June near Green Bay (assisting in the field), then proceed with the sites detailed above throughout July and August. A new graduate student is being added to the UND crew, and a full-time summer technician has been selected for the coming field season.

Data usage/side projects

Central Michigan University:
From October 1st, 2015 through March 31st, 2016, the CMU has been working with data collected from 2011 to 2015 to build metrics for IBIs. This process involves exploratory analyses and the construction of disturbance gradients upon which wetland sites are placed. Preliminary results have shown support for metrics built in previous years, which speaks to the strength of the coastal wetland IBIs.

Oregon State University:
The OSU team continued to work with Laura Chavez to assist in training plant samplers and also provided plant data for studying paired treated and untreated *Phragmites* plots. Dennis Albert met on Neebish Island with tribal biologists of the Sault Ste. Marie tribe, Loyola University Chicago researchers, Dartmouth University professor Nick Reo, and a post-doc to discuss how GLRI marsh data that was collected on the St. Marys River and Neebish Island could be used as base-line data for a tribal coastal restoration project on Sand Island, a small island between Sugar and Neebish Islands.

GLRI data was also used as baseline data for two additional GLRI projects: "Sustainable Restoration for Great Lakes Coastal Wetlands", with a second phase titled "Furthering capacity to maintain high quality coastal wetlands in N. MI. " Partners in these projects were Loyola University Chicago, De Paul University, University of Michigan, Lake Superior State, and Oregon State University, and the projects resulted in the harvest of 30 acres of hybrid cattail (*Typha* x *glauca*) at Cheboygan (Figures 27 and 28) and 7 acres at Cedarville, as well as additional hybrid cattail harvests on Sand Island in the St. Marys River and Mentor Marsh near Cleveland, OH.

Figure 27. One of several hybrid cattail harvest and restoration sites at Cheboygan, MI.

Plant sampling was also conducted at the Maumee Bay (Erie Marsh Hunt Club) restoration site, where an underwater channel was constructed to reconnect 250 acres of diked marsh back to Lake Erie, and other dike upgrades and treatment of invasive plants continued into 2015.

Important results:

- A high quality Lakeplain Lake Prairie complex, a rare plant community throughout the Great Lakes region, was found during our plant survey of St. Johns marsh in an area that had been proposed for a dike enhancement project by the Michigan DNR (Figure 29). The site contains abundant milkweed plants, which appear to include both common milkweed (*Asclepias syriaca*) and rare Sullivant's milkweed (*A. sullivantii*, awaiting confirmation), both of which were being used by monarch butterflies. The survey has resulted in ongoing discussions concerning the proposed boundaries of the project.
- The plant indicator was revised for SOLEC 2016 during the fall of 2015. Nick Danz played a major role in the data analysis, and almost all plant sampling teams provided valuable insights that were incorporated into the indicator revisions.
- No new invasive plant species were documented in Michigan.

- No expansions of the invasive species frog-bit (*Hydrocharis morsus-ranae*) were documented in either Lake Michigan or Lake Superior.

Figure 28. Harvesting hybrid cattail as part of Cheboygan, MI coastal restoration project.

- Both sampling teams continued to separate *Phragmites australis* occurrences into native and invasive populations to improve tracking of invasiveness of this species. There did not seem to be any problems making this separation.
- Sites with ongoing mowing and *Phragmites* treatment by private landowners were greatly reduced in 2015 due to high water levels.
- 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. As in past years, 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*), but these were less abundant than in past years because of high water levels. None of these orchids are federally or state listed species, but as orchids they have protection from commercial harvest under state regulations.
- Sampling was much slower with increased water levels on all of the lakes due to high water levels.

Figure 29. GLRI sampling site at St. Johns Marsh, July 23, 2015.

- Some signs of *Phragmites australis* mortality were seen resulting from storm waves, but these dead plants were at the outer edge of the beds, and were pushed into a thick, dense wrack that reduced storm damage to the *Phragmites* beds closer to shore. This appears to indicate that *Phragmites* beds may be protected from large-scale destruction in many of the beds that expanded during the 1999-2013 low water years.
- The one-meter increase in water depth in 2014 and 2015 has resulted in wide-scale erosion of many wetland macrophytes, including shrubs. These destroyed 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.

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

Sample Processing, Data Entry, and Quality Control Checks

The College at Brockport aquatic macroinvertebrate personnel, overseen by Mr. Gary Neuderfer, have completed 100% of all macroinvertebrate identification from 2015 sampling. Graduate students and undergraduate technicians, overseen by Dr. Douglas Wilcox and Mr. Brad Mudrzynski, have both entered and performed quality control checks on all data generated from the 2015 sampling season, including all bird, amphibian, fish, water quality, aquatic macroinvertebrate, and vegetation data.

Important 2015 Findings

The plant, fish, and bird summaries shown below give a coarse snapshot of wetland biota trends within the area that The College at Brockport sampled. This region is primarily the US shore of Lake Ontario; however, The College at Brockport sampled five Canadian sites for all protocols and one Lake Erie site for vegetation only. Only one plant species of conservation need, Beck's water-marigold (*Bidens beckii*), was found during sampling and was present in 10.5% of the sites sampled (Table 15).

Table 15. Plant species of conservation need encountered The College at Brockport during 2015 sampling. All individuals were found on Lake Ontario.

Species	Common Name	Percent of Sites	New York Status
Bidens beckii	Beck's water-marigold	10.5	Threatened

Invasive plants, however, were very common throughout Lake Ontario. Narrow-leaf cattail (*Typha angustifolia*), hybrid cattail (*Typha x glauca*), European frogbit (*Hydrocharis morsus-ranae*), and Eurasian water-milfoil (*Myriophyllum spicatum*) were all found in at least 70% of the sites that The College at Brockport sampled in 2015 (Table 16). One other invasive plant species, common reed (*Phragmites australis*), was noted as present at four sites, or 19% of those sampled, but was contained in small patches that did not occur on sampling transects. Despite not being detected in quadrats and its low frequency of occurrence in Lake Ontario, the patches observed were dense monocultures.

Table 16. Invasive plant species encountered by The College at Brockport during 2015 sampling.

Species	Common Name	Percent of Sites
Typha angustifolia	Narrow-Leaf Cattail	100.0
Typha x glauca	Hybrid Cattail	94.7
Hydrocharis morsus-ranae	European Frogbit	84.2
Myriophyllum spicatum	Eurasian Water-Milfoil	73.7
Solanum dulcamara	Bittersweet Nightshade	57.9
Potamogeton crispus	Curly Pondweed	47.4
Lythrum salicaria	Purple Loosestrife	42.1
Phalaris arundinacea	Common Reed	21.1
Circium arvense	Field Thistle	10.5
Acorus calamus	Sweet Flag	10.5
Trapa natans	Water Chestnut	10.5
Lonicera x bella	Bella Honeysuckle	5.3
Butomus umbellatus	Flowering-Rush	5.3
Myosotis scorpioides	Forget-Me-Not	5.3
Lysimachia nummularia	Pennywort	5.3
Iris pseudacorus	Yellow Iris	5.3

No fish species of conservation need were captured in 2015 by The College at Brockport crews; however, a few introduced species were detected. Round goby (*Negobius melanostomus*) was the most prevalent introduced species found by crews in 2015, yet was detected at only 30% of the sites (Table 17). White perch (*Morone americana*) was the next most common invasive species caught by The College at Brockport in 2015 and was present at 20% of the sites sampled. The remaining invasive fish species caught were common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), rudd (*Scardinius erythropthalmus*), and alewife (*Alosa pseudoharengus*), all of which occurred at 10% or fewer of the 2015 sites sampled by The College at Brockport. All of these invasive fish were generally few in number at the sites where they were caught.

Table 17. Non-native and invasive fish species encountered by The College at Brockport during 2015 sampling.

Common Name	Scientific Name	Percent of Sites
Round Goby	*Neogobius melanostomus*	30.0
White Perch	*Morone americana*	20.0
Common Carp	*Cyprinus carpio*	10.0
Goldfish	*Carassius auratus*	10.0
Rudd	*Scardinius erythropthalmus*	10.0
Alewife	*Alosa pseudoharengus*	5.0

Three bird species of interest were detected by The College at Brockport surveyors in 2015. Two of these, Mute Swan (*Cyngus olor*) and European Starling (*Sturnus vulgaris*), were invasive species and were detected at 8.0 and 4.0% of the sites sampled, respectively (Table 18). Common Nighthawk (*Chordeiles immer*), listed as a “special concern” species in New York State, was the only bird species of conservation need detected by The College at Brockport surveyors in 2015 and was present in only 4.0% of sites. No endangered, threatened, special concern, or invasive amphibian species were detected in 2015 by The College at Brockport.

Table 18. Bird species of conservation interest, either due to threatened, special concern, or invasive status, encountered by The College at Brockport during 2015 sampling.

Common Name	Scientific Name	Percent of Sites	Status
Mute Swan	*Cyngus olor*	8.0	Invasive
Common Nighthawk	*Chordeiles immer*	4.0	Special Concern
European Starling	*Sturnus vulgaris*	4.0	Invasive

Water quality metrics for the sites that The College at Brockport sampled varied widely, with a general trend of better water quality in the eastern and northern Lake Ontario sites and poorer quality along the southern shore. For example, the site with the greatest total phosphorus (0.360 mg/L) and orthophosphorus (0.271 mg/L) was the same site that had the darkest color water (216.0 pt-co) (Table 19). This site, Brush Creek, was located in an agricultural landscape on Lake Ontario’s southern shore and was sampled after a rainstorm. In contrast, the site with the lowest total phosphorus (0.021 mg/L) and orthophosphorus (0.003) was The Isthmus, a lacustrine site located on Lake Ontario’s northeast shore that had almost no upland watershed and therefore had little upstream influence on water quality. The remaining water quality metrics largely followed this geographic trend in water quality.

Table 19. Minimum, maximum, and mean water quality values from sites sampled by The College at Brockport in 2015.

	Chl (µg/L)	Phaeo (µg/L)	TP (mg/L)	OP (mg/L)	TN (mg/L)	NH4-N (mg/L)	NO2/NO3-N (mg/L)	color (pt-co)	Cl (mg/L)
Min	0.0	0.1	0.021	0.003	0.252	0.000	0.000	14.5	3.90
Max	46.3	77.1	0.360	0.271	1.868	0.092	0.688	216.0	120.30
Mean	5.8	9.2	0.111	0.046	0.811	0.025	0.091	75.8	50.18

The Lake Ontario sites that The College at Brockport sampled for aquatic macroinvertebrates in 2015 were dominated by the species *Hyalella azteca* and genus *Gammarus*, both scuds (or amphipods), which collectively made up over 44% of all aquatic macroinvertebrates identified (Table 20). The third most prevalent taxa collected was the sub-family of non-biting midges Chironominae, which made up 8.28% of the aquatic macroinvertebrates collected. Two invasive species of concern in Lake Ontario were also collected; however, both species were infrequent and few in number. *Bithynia tentaculata* and *Dreissena polymorpha* represented 0.32 and 0.03% of all aquatic macroinvertebrates collected in 2015, with 35 and 2 individuals each.

Table 20. Count and percentage of all 2015 lab identifications for the most common aquatic macroinvertebrate and select non-native taxa.

Taxa	2015 Count	Percent of All 2015 Taxa
Hyalella azteca	3326	30.29
Gammarus	1575	14.35
Chironominae	909	8.28
Bithynia tentaculata	35	0.32
Dreissena polymorpha	2	0.03

2015 Benchmarks and Data Sharing

The College at Brockport continued to sample many sites within the Rochester embayment Area of Concern as benchmarks to aid in numerous restoration projects. Buck Pond and Buttonwood Creek were sampled to provide data for an ongoing Ducks Unlimited restoration project that aims to reduce the impacts of invasive cattail, provide spawning and nursery areas for northern pike (*Esox lucius*), and create habitat for waterfowl. Braddock Bay was also sampled as a benchmark in 2015 to provide more pre-restoration data for the US Army Corps of Engineers restoration project that will reduce wave attack, wetland loss, and turbidity by re-creating the lost barrier beach, and will reduce cattail to provide spawning and nursery areas for northern pike and potential habitat for black terns. Finally, The College at Brockport worked with various rapid-response, invasive species removal crews by providing them with new sightings of infestations. The most notable of these was water chestnut (*Trapa natans*), which was only detected in two sites with official vegetation surveys but was observed in at least four other sites.

2016 Site List and Crew Assignments

The College at Brockport is finalizing its 2016 site list, with the greatest focus on gearing up bird and amphibian survey crews, since they will be the first in the field. Braddock Bay (7052), Buttonwood Creek (7026), and Buck Pond (51) have all received benchmark designation to collect pre- and post-restoration data for various Ducks Unlimited, US Army Corps of Engineers, and US Fish and Wildlife Service GLRI-funded restoration projects. The College at Brockport personnel are currently filling out access permits for sites that are on New York State Department of Environmental Conservation and New York States Parks Recreation and Historic Preservation property. Bird and amphibian training has begun, and crew-members have passed amphibian certification exams; however, they have not attempted the bird identification exams yet. Finally, crew-members are starting equipment and inventory checks to prepare for the summer fish, aquatic macroinvertebrate, water quality, and vegetation sampling.

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)

Sample Processing and Data Entry (2015)

All field data collected during the 2015 field season have been uploaded and QA'd. New sites for 2016 have been assessed by remote examination. Preliminary assessments of site accessibility and suitability for sampling by the other teams is also complete. Correspondence is underway with liaison representatives of several First Nations in Ontario to facilitate access to sites on their lands designated for surveys in 2016.

All fish, macroinvertebrate, macrophyte and water quality data collected in 2015 were compiled and entered into the database and quality assured over the winter. Specimens received from companion labs (part of the reciprocal exchange of macroinvertebrate specimens to ensure consistency of identification) have been identified and returned to the sample owners.

Sampling for fishes in Canada requires approval by the University of Windsor's Animal Use Care Committee as well as permits for Scientific Collection of Aquatic Species (Ontario Ministry of Natural Resources), compliance with the Province of Ontario's Environmental Protection Act (Ontario Ministry of Natural Resources), and Species At Risk (Fisheries & Oceans Canada), and Wild Animal Collection (Ohio Department of Natural Resources). Permit renewal applications are in progress to ensure approval by the start of the sampling season. Reports to the permit granting agencies for 2015 collections were submitted and approved in late fall. Detailed records of fishes caught were sent to local conservation and refuge managerial groups in Ontario and Ohio where appropriate.

Field Training

Many of the individuals who will participate in fieldwork in 2016 were involved in sampling during the 2015 and earlier field seasons. Consequently, only refresher training will be undertaken for them. New recruits include three individuals for the Tozer amphibian-and-bird team, (trained and tested at Port Rowan, ON in early spring 2016 as described in earlier spring semiannual reports) Six people will be collecting data for the project in 2016. Amphibian surveys are currently in progress, and bird surveys will begin shortly. An unusually mild winter and early spring weather have likely sped the arrival of birds this year.

Field crew members working with fishes, macroinvertebrates, and water quality sampling will receive orientation during the last week of April 2016 and will conduct pilot sampling at a local site (to be determined) during late May. All members of the 6-person Windsor field crew from 2015 will be involved to some extent in training and/or field work in 2016. They will train 3-5 new senior undergraduate students who will assist during selected field trips. The Canadian Wildlife Service will have 6 personnel to conduct work on Lake Ontario in 2016, three of whom will be new recruits (receiving training in April). Training review will include GPS use, determination of whether sites meet project criteria (open water connection to lake, presence of a wetland, safe access for crew), identification of vegetation zones to be sampled, collection of water quality samples (including preprocessing for shipment to water quality labs) and calibrating and read field instruments and meters. Other review will include refresher instructions in setting, removing, cleaning and transporting fyke nets, and special emphasis on collection of voucher information (proper photographic procedures, collection of fin clips for DNA analysis, or retention of specimens for lab verification of identity), protocols for collecting and preserving macroinvertebrates using D-frame dip nets and field-picking. Crews will review field data sheet entry procedures, including changes to the data sheets implemented since last field season. All field personnel will be given refreshers in basic fish identification training.

Two new team members (Danielle Gunsch, Daniel Picard) will take the Royal Ontario Museum course in fish identification, which is required of at least one team member in possession of an Ontario Scientific license to collect fishes. Crew leader Janice Gilbert and research assistants Stephanie Johnson and Justin Landry have previously completed this or an equivalent course. All field team members will receive field and lab safety training. Vegetation survey training will be led in early June by team leader Carla Huebert near Windsor, ON. Vegetation assistants will be introduced to the specific vegetation sampling methodology and data recording methods outlined in the QAPP.

Related Research in Progress

In 2015, fish data were analysed by graduate student Jeffrey Buckley (M.Sc. 2015) to compare the consistency of classification of wetland condition using analytical metrics derived by several different investigators. Buckley compared the wetland IBI of Cooper et al. with the fish quality indices of Seilheimer et al., and a new multivariate index (Fish Assemblage Condition Index (FACI) based on the reference-degraded continuum approach (Bhagat et al. in prep.). The Cooper et al. and Seilheimer et al. and FACI indices all exhibit high degrees of sensitivity and specificity to degradation by anthropogenic stress when used to assess the sites from which data were originally gathered. The indices' ability to accurately assess the condition of sites sampled over the past few years is somewhat reduced but still considered to be acceptable.

M.Sc. student Jasmine St Pierre gave a presentation at the 2015 IAGLR conference.

Examples of Leveraged Project Benefits

The Canadian Wildlife Service – Ontario Region has been working to better understand factors related to the presence of *Nitellopsis obtusa* in the Great Lakes coastal wetlands. The CWM project has allowed the program to extend surveillance to additional wetlands in Lake Ontario. This species is of great conservation concern because its current distribution and potential impacts on fish and wildlife are unknown. It was first recorded in the Great Lakes basin in the late 1970s and has not received a great deal of attention until it was more recently rediscovered.

In addition, the CWS is interested in determining the natural variability in Index of Biotic Integrity values during sampling events in coastal wetlands. This will allow agencies to 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 great interest for resource management agencies and partners who are looking for assistance in interpreting changes in biotic indices through time, especially with respect to pre- and post-restoration projects. The CWM project has allowed CWS staff to collect information at additional sites to supplement its current study.

Special efforts were continued in 2015 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 possibly solicit collaborations. Although we continue our efforts to contact the environmental liaison individuals for First Nations lands we again had limited success in collaborating with them

We engaged in discussion and/or site visits with the following individuals or groups during the 2015 field season:

Greg Mayne (Environment Canada, Canadian Co-chair, Lake Huron Binational Partnership) and Scott Parker (Parks Canada, Fathom Five National Park), and Geoff Peach (Lake Huron Center for Coastal Conservation) We provided summaries of coastal wetland condition on the Bruce Peninsula and other Lake Huron locations. We will continue to work with these individuals in summarizing wetland condition in anticipation of preparing a report for the Lake Huron Binational Partnership on the current status of Lake Huron and research needs leading to the 2016 Intensive Study Year for Lake Huron.

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 again in 2014. Collaboration with the USGS lab is continuing. 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 with within-year variability both on sampling effectiveness and on the precision of multimetric and multivariate indicator scores calculated from the data.

ASSESSMENT AND OVERSIGHT

The project QAPP was approved and signed on March 21, 2011. A revised QAPP (r4) was approved and signed on February 15, 2014. This QAPP was reviewed in early 2015 and personnel changes were updated, as reported in the fall 2015 report. The revised QAPP_r5 was signed by all co-PIs on January 23, 2015 and was signed by US EPA on March 25, 2015. No further changes were made to the QAPP, but it will be reviewed and updated again at the 2017 PI meeting.

Major QA/QC elements that were carried out over the previous 6 months 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 over the winter). 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 is being checked to verify consistency between the primary record (e.g., field data sheet) and the database. This has been completed for nearly all data that has been entered into the database over the past six months and is a requirement before data are analyzed or used to calculate IBI metrics. Data that still require QC have been identified and regional labs were notified and are currently finishing these checks.

- Macroinvertebrate QC checks: Each regional lab that is processing 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 processes the sample as usual and sends the IDs and counts to the QA managers. The QA managers then compare the original IDs with the QC IDs to determine correspondence between the two labs. Inconsistencies in taxa IDs are resolved by a 3rd or 4th lab when necessary or by additional taxonomic experts, depending on the nature of the discrepancy. At present, most labs have made the required swaps for 2015 samples and many have completed the required processing. After QA managers compare original and QC taxa IDs and counts, and resolve discrepancies, they will communicate 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: The only mid-season QC check that was required over the previous six-month period was for macroinvertebrate processing. Regional lab leaders conducted these mid-season checks and were responsible for remedying any problems that were detected. The macroinvertebrate sample swaps are an additional measure to ensure consistent taxonomy.

- Creation/maintenance of specimen reference collections: Reference collections for macroinvertebrates, fish, and plants are being created or maintained by each regional team. Macroinvertebrate reference collections, in particular, were developed or expanded over the previous six months as these samples have been processed.

- 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 calculated over the past six months and will be archived by each regional laboratory.

- Nutrient detection limits: QC managers discovered that some regional labs have been entering data that are 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 limit. Therefore, we developed a standard way for labs to enter their data at the precision of their lab's instrumentation and have the data management system archive and deliver 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.

- Bird and amphibian crews begin their field season in mid-April. All training and certification of crew members has been completed or will be completed soon, prior to crew members working independently. Records of this training and certification are being compiled and archived at each respective regional lab and with the QA managers.

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 21) or have been flagged accordingly.

Table 21. 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 four project years is shown in Table 22. 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, and in these instances the QA officer will determine whether data are acceptable. It is also important to note that RPD on field duplicates incorporates environmental (e.g., spatial) variability, since duplicate samples are collected from adjacent locations, as well as analytical variability (e.g., instrument drift). Therefore, RPD of field duplicates is generally higher than RPD of laboratory duplicates. Table 22 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. Acceptance of data associated with higher than expected RPD was determined by the QA officers. The maximum expected RPD values are 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 22. 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 officers have assessed RPDs per laboratory to identify any potential analytical performance issues (Table 23). 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 23. 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 continue to maintain close communication as the project enters the fifth year. The lead PI, all co-PIs, and many technicians attended an organizational meeting in Midland, Michigan on February 19th, 2016. During this meeting, the group discussed issues pertaining to manuscript topics and final report products. Conclusions from the sampling of benchmark sites over the past five years was also a conversation topic with ideas being shared about what conclusions could be made from these data. Dr. Kevin O'Donnell (EPA) also discussed future coastal wetland restoration projects and how our group could contribute by monitoring the success of these efforts. Personnel from USGS introduced their idea for a collaborating project that would include fall and spring sampling for fish, macroinvertebrates, and water quality in order to better understand the functions that wetlands provide to near-coastal areas. For example, what fish breed in the wetlands or use them as nursery areas? How much invertebrate export is there to the surrounding landscape? USGS will work with CWM field crews to see which sites can be sampled and associated costs. USGS hopes to have sufficient funding to cover all additional sampling costs.

The current version of the QAPP and SOPs (Revision 5) updates personnel changes in the last several years and provides an alternate vegetation sampling protocol for wide, dense *Phragmites* stands. It has been signed by all personnel and the EPA.

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 spend the first week of field season in the field with their crew to ensure that all protocols are being followed according to the standards set forth in the QAPP and SOPs and to certify or re-certify crew members. Most crews have many returning and experienced personal, which will make training and sampling efficient in 2016. PIs keep in close contact with crews via cell phone, text, and email, and the leadership team is 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 the fifth sampling season. This is due to the leadership and safety consciousness of PIs, field crew chiefs, and field team leaders. 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 work. PIs continued to be 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 that 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 arise. The fifth year of this project was extremely successful and we anticipate an equally successful continuation of sampling.

LEVERAGED BENEFITS OF PROJECT (2010 – 2015)

This project has generated a number of spin-off projects and serves as a platform for many graduate and undergraduate thesis topics. In addition, project PIs are collaborating 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 supports or partially supports 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 wetlands, 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 is being studied as a benchmark site for the CWM project. As a benchmark site, Erie Marsh Preserve will serve as a comparison against randomly-selected project sites, and will be 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 data set 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 utilized data collected during the first three years of the GLRI study. 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. With 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 is being 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 System 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 propose to develop a new Decision Support System (DSS) to prioritize protection and restoration investments. This 2-year project, funded by the Upper Midwest and Great Lakes Landscape Conservation Cooperative, will develop a DSS for wetlands from Saginaw Bay to Western Lake Erie.

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 is underway under CWM 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 are being 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 bird 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 has developed a draft set of indicator metrics for submission 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 March 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 GLCWM 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 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). We have ongoing communication with TNC members and plan to re-sample of this site in 2015.

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 is working on 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). We have provided her with vegetation data and sampling locations each year to assist with this effort. Dr. Bourgeau-Chavez was also just given funding to assess herbicide effectiveness against *Phragmites* in Green Bay and Saginaw Bay. CWM data are being 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 have also realized that they may be discovering new locations of invasive species, particularly invasive macroinvertebrates. To ensure that all new sightings get recorded, we are 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 2017-2017, vegetation PI N. Danz has 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 have received many requests to sample particular wetlands of interest to various agencies and groups. In some instances the wetlands are scheduled for restoration and it is hoped that our project can provide pre-restoration data, and perhaps also provide post-restoration data to show the beginnings of site condition improvement, depending on the timing. 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 increase efficiency and effectiveness of restoration efforts across the Great Lakes basin.

At some sites, restoration is still in the planning stages and restoration committees are interested in the data CWM can provide to help them create a restoration plan. This is happening 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 have 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 have come 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 has 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 are working 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 is requesting 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 have 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 will focus 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 has been notifying 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 are also now receiving requests to do methods comparison studies. For example, USGS and Five Fathom National Marine Park have both requested data and sampling to compare with their own sampling data.

Overall, CWM PIs have had many requests to sample specific wetlands. It has been 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)

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): 30 + 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: 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

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. In revision. Nitrogen limitation of algal biofilms in coastal wetlands of Lakes Michigan and Huron. *Freshwater Science.*

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

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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
2. http://www.wwmt.com/news/features/top-stories/stories/Snail-harmful-to-ducks-spreading-in-Great-Lakes-63666.shtml
3. http://fox17online.com/2014/12/16/gvsu-researchers-find-more-of-invasive-snail-species-in-lake-michigan/
4. http://www.ourmidland.com/news/cmu-scientists-identify-spread-of-invasive-species/article_e9dc5876-00f4-59ff-8bcd-412007e079e8.html
5. http://www.therepublic.com/view/story/4cde108b10b84af7b9d0cfcba603cf7a/MI--Invasive-Snails
6. http://media.cmich.edu/news/cmu-institute-for-great-lakes-research-scientists-identify-spread-of-invasive-species
7. http://www.veooz.com/news/qHv4acl.html
8. http://www.gvsu.edu/gvnow/index.htm?articleId=1E55A5C5-D717-BBE7-E79768C5213BB277
9. http://hosted2.ap.org/OKDUR/99dded7a373f40a5aba743ca8e3d4951/Article_2014-12-16-MI--Invasive%20Snails/id-b185b9fd71ea4fa895aee0af983d7dbd
10. http://whitehallmontague.wzzm13.com/news/environment/327493-my-town-waterfowl-killer-spreads-great-lakes-basin
11. http://www.timesunion.com/news/science/article/Snail-harmful-to-ducks-spreading-in-Great-Lakes-5959538.php
12. http://grandrapidscity.com/news/articles/gvsu-researchers-find-more-of-invasive-snail-species-in-lake-michigan
13. http://myinforms.com/en-us/a/8645879-gvsu-researchers-find-more-of-invasive-snail-species-in-lake-michigan/
14. http://usnew.net/invasive-snail-in-the-great-lakes-region.html
15. http://www.cadillacnews.com/ap_story/?story_id=298696&issue=20141216&ap_cat=2
16. http://theoryoflife.com/connect/researchers-track-invasive-9251724/
17. http://snewsi.com/id/1449258811
18. http://www.newswalk.info/muskegon-mich-new-scientists-say-742887.html
19. http://www.petoskeynews.com/sports/outdoors/snail-harmful-to-ducks-spreading-in-great-lakes/article_b94f1110-9572-5d18-a5c7-66e9394a9b24.html
20. http://www.chron.com/news/science/article/Snail-harmful-to-ducks-spreading-in-Great-Lakes-5959538.php
21. http://usa24.mobi/news/snail-harmful-to-ducks-spreading-in-great-lakes
22. http://www.wopular.com/snail-harmful-ducks-spreading-great-lakes
23. http://www.news.nom.co/snail-harmful-to-ducks-spreading-in-14203127-news/

24. http://www.mlive.com/news/muskegon/index.ssf/2014/12/hard_to_kill_invasive_faucet_s.html
25. http://wkar.org/post/researchers-eye-spread-invasive-faucet-snails
26. http://www.greenfieldreporter.com/view/story/4cde108b10b84af7b9d0cfcba603cf7a/MI--Invasive-Snails
27. http://www.natureworldnews.com/articles/11259/20141217/invasive-snails-killing-great-lake-birds.htm
28. http://www.wsbt.com/news/local/snail-harmful-to-ducks-spreading-in-great-lakes/30251286
29. http://www.wtkg.com/articles/wood-news-125494/invasive-and-deadly-snail-found-in-13073963
30. http://www.techtimes.com/articles/22378/20141218/invasive-snail-problem-in-great-lakes-difficult-to-deal-with-says-experts.htm
31. http://perfscience.com/content/214858-invasive-snails-kill-birds-great-lakes
32. http://www.hollandsentinel.com/article/20141216/NEWS/141219279
33. http://www.woodradio.com/articles/wood-news-125494/invasive-and-deadly-snail-found-in-13073963
34. http://www.full-timewhistle.com/science-27/great-lake-invasive-snails-kill-birds-265.html
35. http://www.islamabadglobe.com/invasive-deadly-snails-are-more-dangerous-than-we-thouht-805.html
36. http://americanlivewire.com/2014-12-17-invasive-snail-species-attack-birds-great-lakes/
37. http://www.seattlepi.com/news/science/article/Snail-harmful-to-ducks-spreading-in-Great-Lakes-5959538.php
38. http://www.pendletontimespost.com/view/story/4cde108b10b84af7b9d0cfcba603cf7a/MI--Invasive-Snails/
39. http://www.wilx.com/home/headlines/Invasive-Snail-Spreading-in-Great-Lakes-285933261.html
40. http://www.watertowndailytimes.com/article/20150119/NEWS03/150118434
41. http://howardmeyerson.com/2015/01/15/scientists-invasive-snail-more-prevalent-than-thought-poses-grave-danger-to-waterfowl/

Mock-up of press release produced by collaborating universities.

FOR IMMEDIATE RELEASE: December 9, 2014

CONTACT: June Kallestad, NRRI Public Relations Manager, 218-720-4300

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.