Great Lakes Coastal Wetland Monitoring Program

Semiannual Progress Report

April 1, 2017 – September 30, 2017

Prepared for:
U.S. EPA GLNPO (G-17J) 77 W. Jackson Blvd. Chicago, IL 60604-3590
Contract/WA/Grant No./Project Identifier:
GL-00E00612-0

Prepared by:
Dr. Donald G. Uzarski, Principal Investigator
CMU Institute for Great Lakes Research
CMU Biological Station
Department of Biology
Central Michigan University
Brooks 127
Mount Pleasant, MI 48859

Dr. Valerie J. Brady, QA Manager
Center for Water and the Environment
Natural Resources Research Institute
University of Minnesota Duluth
5013 Miller Trunk Highway
Duluth, MN 55811-1442

Dr. Matthew J. Cooper, QA Manager
Burke Center for Freshwater Innovation
Northland College
1411 Ellis Avenue
Ashland, WI 54891

INTRODUCTION

Monitoring the biota of Great Lakes coastal wetlands began as a project funded under the Great Lakes Restoration Initiative on 10 September 2010. The project had the primary objective of implementing a standardized basin-wide coastal wetland monitoring program. Our first five years of sampling (2011-2015) set the baseline for future sampling years and showed the power of the datasets that can be used to inform decision-makers on coastal wetland conservation and restoration priorities throughout the Great Lakes basin. During round 1, we 1) developed a database management system; 2) developed 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) developed background documents on the indicators.

We have now entered the second phase of this work. The status of the work has been changed from a project to a sampling program, and we are sampling all the wetlands again for the second round of this work. During this second round (2016-2020), we will be adjusting our indicators as necessary so that they remain robust to water level fluctuations and we will continue to support wetland restoration projects by providing data and information.

Summary of Round 1 of sampling:
Our first round of sampling, in the project phase, began with the development of our Quality Assurance Project Plan, developing the site selection mechanism, selecting our sites, extensively training all field crew members, and finally beginning wetland sampling. After a few methods adjustments, we updated our QAPP and have kept it updated although relatively minor changes have been necessary since that first year. Crews sampled 176 sites that first year and roughly 200 sites per year each of the next 4 years. Data were entered into an on-line web-interfaced data management system specifically designed to hold those data.

Our yearly sampling schedule proceeds in this manner: During the winter, PIs and crew chiefs meet to discuss issues, update each other on progress, and ensure that everyone is staying on track for QA/QC. Sites are selected using the site selection system by March, and field crew training happens in March – June, depending on biotic type. Amphibian sampling typically begins in late March/early April with bird sampling beginning in April or May, and finally vegetation, fish, macroinvertebrate, and water quality begin in June. Phenology is followed across the basin, so that most southerly sites are sampled earlier than more northerly sites. In the fall and early winter, data are entered into the database, unknown fish and plants are identified, and macroinvertebrates are identified. The goal is to have all data entered and QC'd by February or March. Metrics and IBIs are calculated in late March in preparation for the spring report to US EPA GLNPO.

A full summary of round 1 of sampling was submitted to US EPA and is available at http://www.greatlakeswetlands.org/Reports-Publications.vbhtml.

PROGRAM ORGANIZATION

Figure 1 shows our organization for the 2016-2020 period.

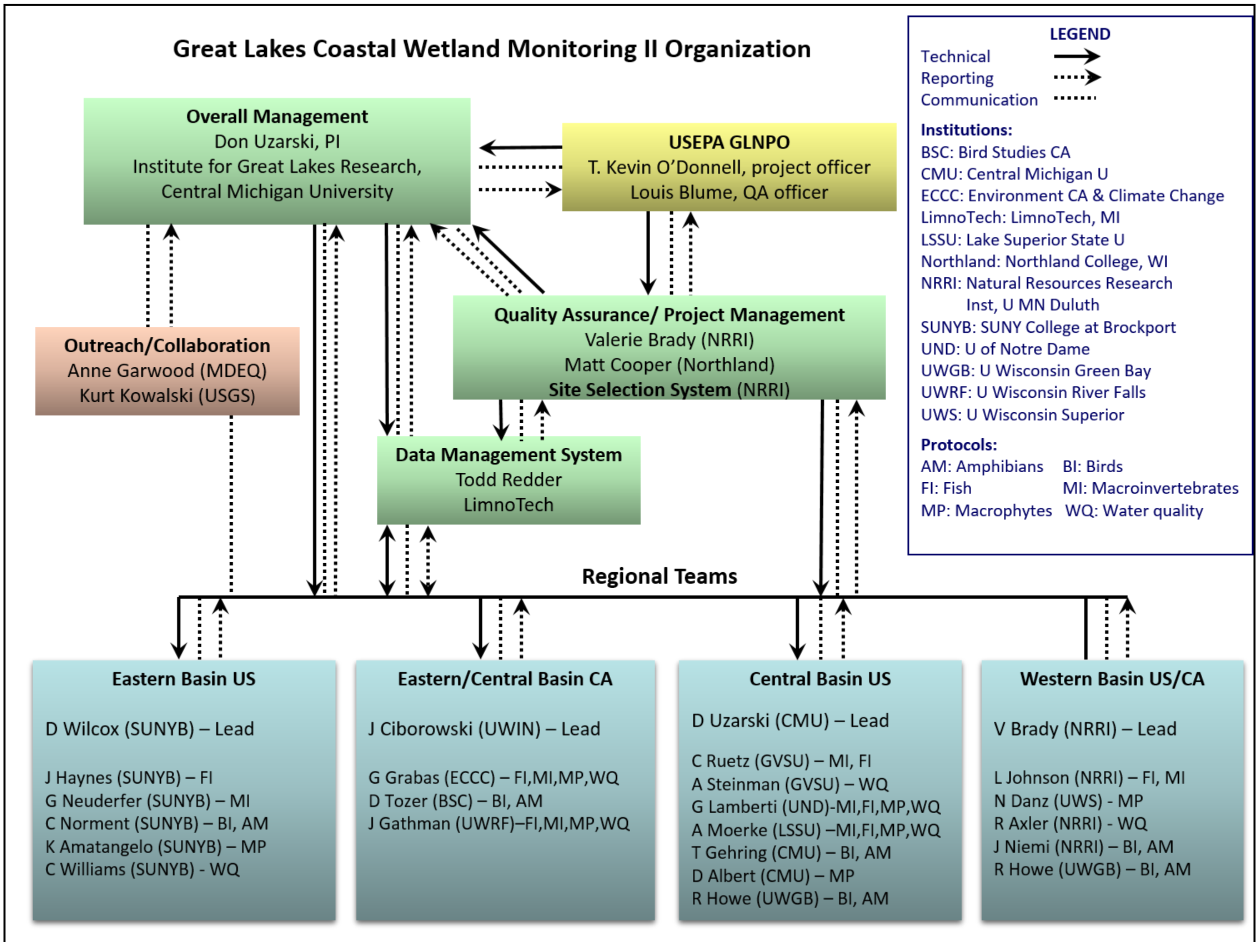

Figure 1. Organizational chart for the program showing lines of technical direction, reporting, and communication separately.

PROGRAM TIMELINE

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

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

Tasks	'15	2016				2017				2018				2019				2020			
	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 updated		X				X				X				X				X			
Site selection for summer			X			X				X				X				X			
Sampling permits acquired			X				X				X				X				X		
Data entry system updated		X	X	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
Report to GLNPO			X		X		X		X		X		X		X		X		X		X

GLRI Action Plan II of Measure of Progress

GLRI Action Plan II **of Measure of Progress**		**Reporting Period** **(April 1, 2017 – September 30, 2017)**	**Project Status** (Not Started; Started; Paused; 25% Completed; 50% Completed; 75% Completed; 95% Completed; and 100% Completed)
4.1.3	Number of Great Lakes coastal wetlands assessed for biotic condition	401	50%

SITE SELECTION

Year seven site selection was completed in March 2017. Because we completed the original Coastal Wetland Monitoring site list in 2015 (year 5), we are now going through that list again. In 2016, we sampled the same site list as was generated for 2011. This summer we sampled the sites sampled in 2012. Differences in the site list between successive sampling rounds (e.g., 2011 vs. 2016) are most often associated with special benchmark sites. 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.

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, 2013, and 2016

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 (or appeared to have) 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. 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.

Table 2. 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**	

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 Georgian Bay (Lake Huron) 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 and to recover with rising 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 determined for each site in the original coastal wetland GIS coverage. 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 ecoregion systems (Omernik / Bailey / CEC).

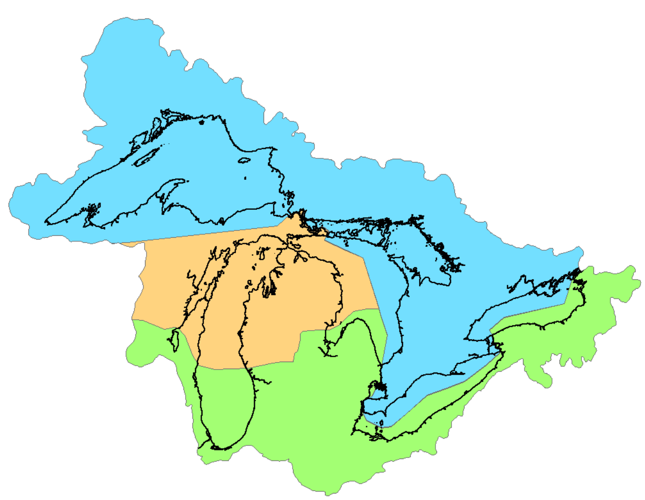

Figure 2. Divisions of lakes into regions. Note that stratification is by region *and* lake, so northern Lake Erie is not in the same region as Lake Superior, etc.

Panelization

Randomization
The first step in randomization was the assignment of selected sites from each of the project's 30 strata (10 regions x 3 geomorphic classes) to a random year or panel in the five-year rotating panel. Because the number of sites in some strata was quite low (in a few cases less than 5, more in the 5-20

range), simple random assignment would not produce the desired even distribution of sites within each strata over time. Instead it was necessary to assign the first fifth of the sites within a stratum, defined by their pre-defined random ordering, to one year, and the next fifth to another year, etc.

In 2012, sites previously assigned to panels for sampling were assigned to sub-panels for re-sampling. The project design's five year rotation with a 10% re-sampling rate requires five panels, *A-E*, and ten sub-panels, *a-j*. If 10% of each panel's sites were simply randomly assigned to sub-panels in order *a-j*, sub-panel *j* would have a low count relative to other sub-panels. To avoid this, the order of sub-panels was randomized for each panel during site-to-sub-panel assignment, as can be seen in the random distribution of the '20' and '21' values in Table 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, panel *A* was sampled for the second time, so the 21 sites in sub-panel *a* of panel *E* became the re-sample sites. 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. The total panel and sub-panel rotation covers 50 years.

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 is 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

Three-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 third page lists information from the database for the site, including site tags, team assignments, and the history of comments made on the site, including information from previous field crew visits.

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.

2017 Site Selection

For 2017, 231 sites were selected for sampling. Of these, 21 are benchmark sites. Another 12 sites are resample sites and 19 are pre-sample sites, which will be resample sites next year (2018). 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 helps ensure that most crews sample them, allowing more complete comparison of year-year variation when the sites are sampled again the next year.

Wetlands have a "clustered" distribution around the Great Lakes due to geological and topographic differences along the Great Lakes coastline. As has happened each sampling season so far, several teams ended up with fewer sites than they had the capacity to sample, while other teams' assigned sites exceeded their sampling capacity. Within reason, teams with excess sampling capacity expanded 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, with more experienced trainers providing assistance as necessary when field crew chief changes take place. As is true every field season, all crew members still had to pass all training tests, and PIs still conducted mid-season QC. As has become standard protocol, the trainers were always available via phone and email to answer any questions that arose during training sessions or during the field season.

The following is a synopsis of the training conducted by PIs in the spring (2017): Each PI or field crew chief trained all field personnel on meeting the data quality objectives for each element of the project; this included reviewing the most current version of the QAPP, covering site verification procedures, providing hands-on training for each sampling protocol, and reviewing record-keeping and archiving requirements, data auditing procedures, and certification exams for each sampling protocol. All field crew members had to pass all training certifications before they were allowed to work unsupervised. Those who did not pass all training aspects were only allowed to work under the supervision of a crew leader who had passed all training certifications.

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

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

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

Additional 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. Additional training on data entry, data uploading, and data QC was provided in 2016 with the implementation of the updated version of the data entry/data archiving system by Todd Redder at LimnoTech. Training on data entry and QC continues via webinar as needed for new program staff.

Certification

To be certified in a given protocol, individuals must pass a practical exam. Certification exams were conducted in the field in most cases, either during training workshops or during site visits early in the season. When necessary, exams were supplemented with photographs (for fish and vegetation) or audio recordings (for bird and amphibian calls). Passing a given exam certifies the individual to perform the respective sampling protocol(s). Since not every individual is responsible for conducting every sampling protocol, crew members were only tested on the protocols for which they are responsible. Personnel who were not certified (e.g., part-time technicians, new students, volunteers) were not 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 (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

The CWMP has been using a web-based data management system (DMS) that was originally developed by NRRI in 2011 to collect field and laboratory data, and then redeveloped by LimnoTech during 2015-16. The new web-based system, which was brought online on April 26, 2016, uses Microsoft’s Active Server Pages .NET (ASP.NET) web application framework running on Windows 2012 Server and hosted on a virtual machine at Central Michigan University (CMU). The open source PostgreSQL Relational Database Management System (RDMS) with PostGIS spatial extensions is used to provide storage for all CWMP data on the same Windows 2012 server that hosts the web application.

The CWMP database includes collections of related tables for each major taxonomic grouping, including vegetation, fish/invertebrates, amphibians, and birds. Separate data entry/editing forms are created for data entry based on database table schema information that is stored in a separate Microsoft Access database. Data entry/editing forms are password-protected and can only be accessed by users that have “Level 4” or “Admin” credentials associated with their CWMP user account.

Specific features of note for the CWMP data management system include:

- Automated processes for individual users to request and confirm accounts;
- An account management page where a limited group of users with administrative privileges can approve and delete user accounts and change account settings as needed;

- Numerous validation rules employed to prevent incorrect or duplicate data entry on the various data entry/editing forms;
- Custom form elements to mirror field sheets (e.g. the vegetation transects data grid), which makes data entry more efficient and minimizes data entry errors;
- Domain-specific “helper” utilities, such as generation of fish length records based on fish count records;
- Dual-entry inconsistency highlighting for amphibian and bird groups using dual-entry for quality assurance; and
- Tools for adding new taxa records or editing existing taxa records for the various taxonomic groups.

The CWMP data management system also provides separate webpages that allow researchers to download “raw” data for the various taxonomic groups as well as execute and download custom queries that are useful for supporting dataset review and QA/QC evaluations as data entry proceeds during and following each field season. Users with a minimum “Level 3” credential are able to access the separate download pages for raw data and custom queries. Organizations that currently have been granted “Level 3” access include GLNPO and its subcontractors and MDEQ. Index of Biological Integrity (IBI) metrics are currently included as a download option based on static scores that reflect data collection through the 2015 field season. A planned upgrade for the system in the coming year is to fully implement and test automated algorithms for calculating IBI metric scores for vegetation, invertebrates, and fish on a regular schedule as data are entered and pass through the QA/QC process.

Raw data downloads are available in both Microsoft (MS) Excel spreadsheet and MS Access database formats, while custom query results are available in spreadsheet format only. All available data/query export and download options are automatically regenerated every night, and users have the option of either downloading the last automated export or generating a new export that provides a snapshot of the database at the time the request is made (the former option is much faster).

In addition to providing CWMP researchers with data entry and download access, the CWMP data management team is providing ongoing technical support and guidance to GLNPO to support its internal management and application of the QA/QC’ed monitoring datasets. GLNPO, with support from subcontractors, maintains a separate, offline version of the CWMP monitoring database within the Microsoft Access relational database framework. In additional to serving as an offline version of the database, this version provides additional querying and reporting options to support GLNPO’s specific objectives and needs under the GLRI. CWMP data management support staff generate and provide to GLNPO and CSRA a “snapshot” of the master CWMP PostgreSQL database as a Microsoft Access database twice per year, corresponding to a spring and fall release schedule. This database release is then used by GLNPO and its subcontractors to update the master version of the Microsoft Access database used to support custom querying and reporting of the monitoring datasets.

A full backup of the CWMP PostgreSQL database is created each night at 3:00 AM Eastern time using a scheduled backup with the PostgreSQL Backup software application. The server that houses the DMS has been configured to use CMU's Veeam Backup Solution. This backup solution provides end-to-end encryption including data at rest. Incremental backups will be performed nightly and stored at secure locations (on premise and offsite). Nightly backup email reports are generated and sent to appropriate CMU IT staff for monitoring purposes. Incremental backups are kept indefinitely and restores can be performed for whole systems, volumes, folders and individual files upon request.

RESULTS-TO-DATE (2011-2017, EXCEPT AS NOTED)

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 project round. Overall, 1010 Great Lakes coastal wetland sampling events were conducted in the first round of sampling (2011-2015; Table 5), and we have now started sampling these wetlands a second time for the second complete round of coastal wetland assessment, 2016-2020. Note that this total number 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. For the second round of sampling, we sampled 192 wetlands in 2016 and 209 wetlands in 2017.

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, each year 60-65% of total sites sampled are US coastal wetlands, with 75-80% 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 nearly all of the large, surface-connected Great Lakes emergent coastal wetlands by count and by area. A few wetlands cannot currently be sampled due to safe access or access permission issues.

Table 5. Counts, areas, and proportions of the Great Lakes coastal wetlands sampled in Round 1 (2011 – 2015) and Round 2 (2016 – 2020) by the GLIC: Coastal Wetland Monitoring Project. Percentages are of overall total sampled each year. Area in hectares.

Country	Site count	Site %	Site area	Area %
Canada				
Round 1: 2011 - 2015				
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 Round 1	**352**	**35%**	**35,137**	**23%**
Round 2: 2016 - 2020				
2016	63	33%	4,336	15%
2017	70	33%	7801	20
CA total Round 2	**133**	**33%**	**12,137**	**18%**
US				
Round 1 (2011 – 2015)				
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 Round 1	**658**	**65%**	**116,309**	**77%**
Round 2: 2016 – 2020				
2016	129	67%	24,446	85%
2017	139	67%	30,703	80%
US total Round 2	**268**	**67%**	**55,149**	**82%**
Overall Totals Round 1	**1010**		**151,446**	
Overall Totals Round 2	**401**		**67,286**	

Teams were able to sample more sites in 2014 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. By 2015 water depths in some coastal wetlands had become so deep that crews had difficulty finding areas shallow enough to set fish nets in zones typically sampled for fish (cattail, bulrush, SAV, floating leaf, etc.). This high water continued into 2017, with Lake Ontario levels reaching highs not seen in many decades. This highlights the difficulty of precisely determining the number of sampleable Great Lakes coastal wetlands in any given year, and the challenges crews face with rising and falling water levels.

The sites sampled in 2017 are shown in Figures 3 and 4 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.

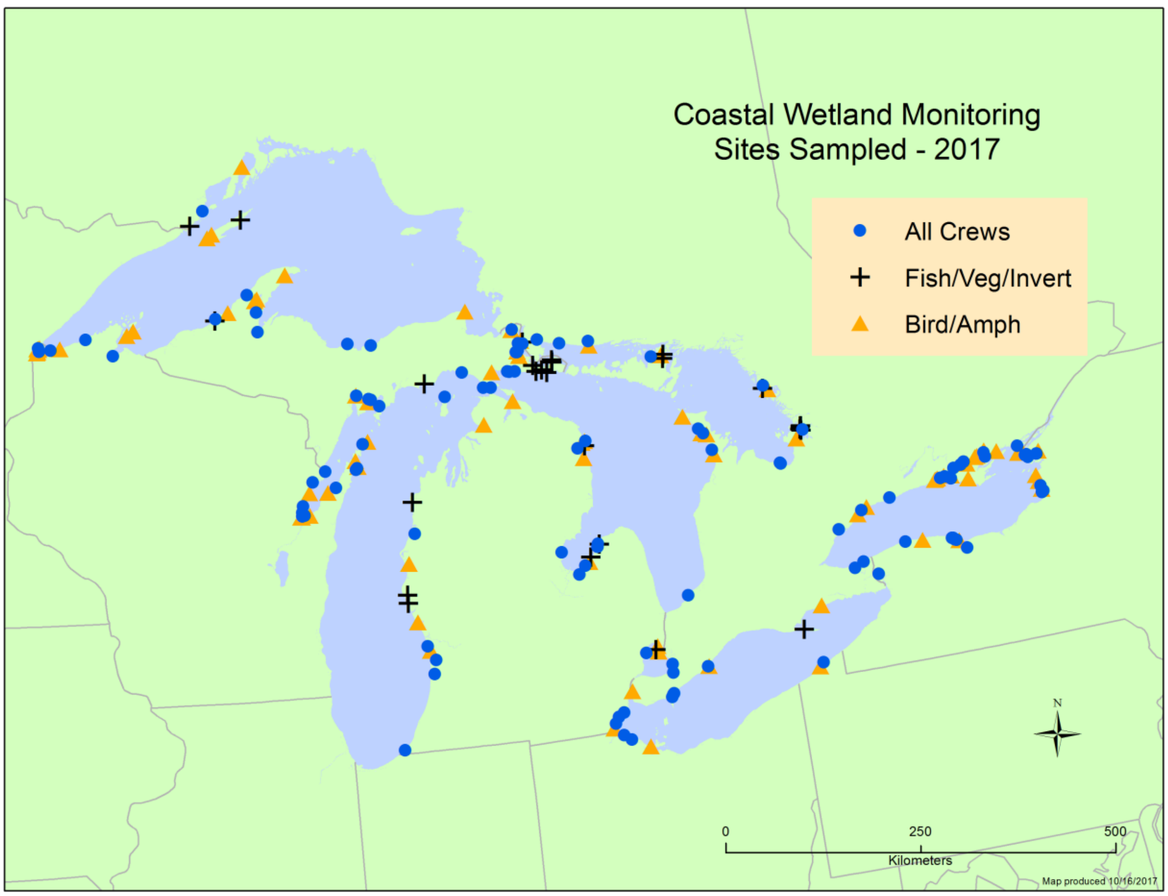

Figure 3. Locations of the 209 Great Lakes coastal wetlands sampled in 2017, color-coded by taxonomic groups. Sites assigned only to bird and amphibian crews (due to their greater sampling capacity) are shown with a gold triangle.

Wetland types are not distributed evenly across the Great Lakes due to fetch, topography, and geology (Figure 4). 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 - 2017 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.

We now have 85 sites that are or have been sampled as a "benchmark." Of these, 37 are to evaluate restoration efforts and 11 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.

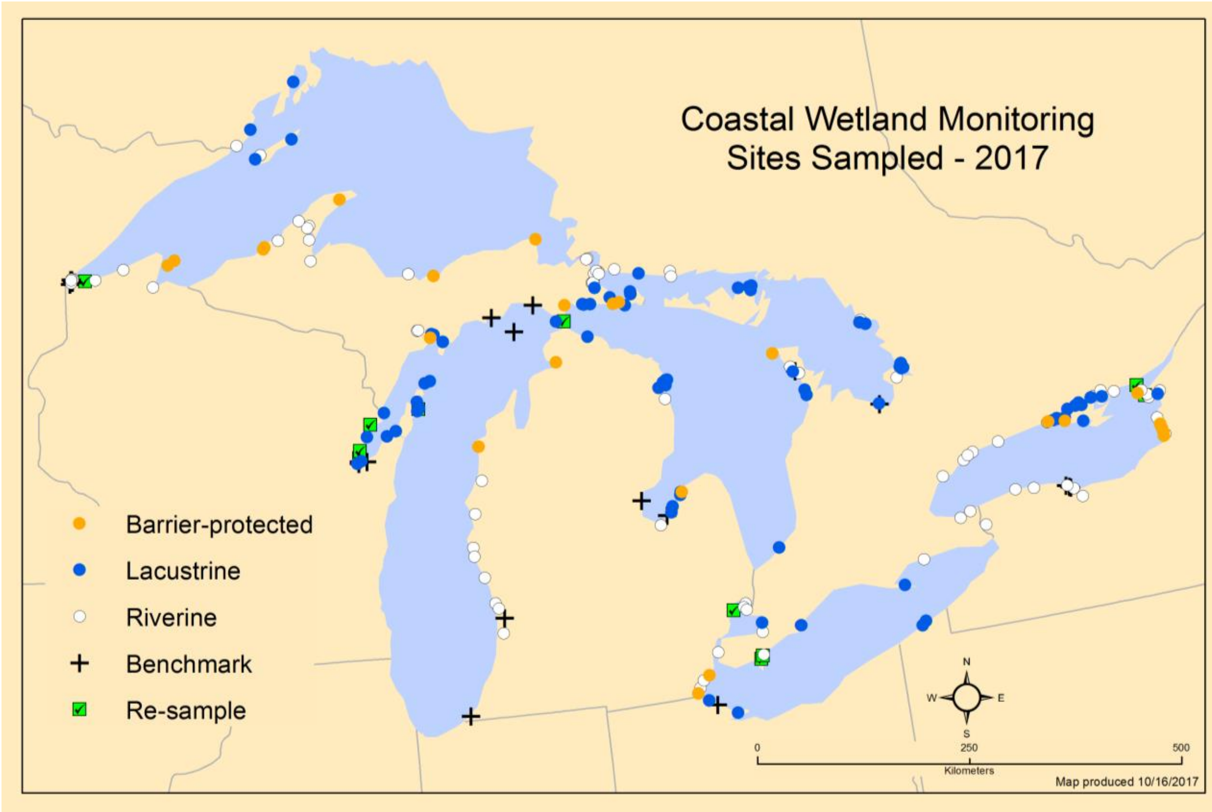

Figure 4. Locations of the 209 Great Lakes coastal wetlands sampled in 2017, color-coded by site type. Wetland types exhibit a clumped distribution across lakes due to geology and topography.

We can now compile good statistics on Great Lakes coastal wetlands because we have sampled nearly 100% of the medium and large coastal wetlands that have a surface water connection to the Great Lakes and are hydrologically-influenced by lake levels. The following indicators and information have not yet been updated for 2016 and 2017 because we are still implementing metric and indicator calculations into our new database system.

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 5). 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.

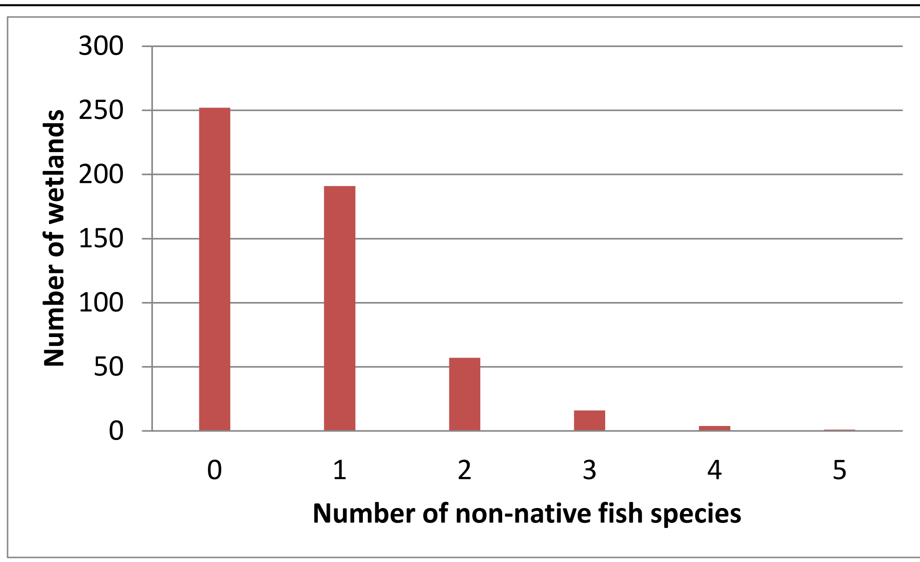

Figure 5. Number of Great Lakes coastal wetlands with non-native fishes. Data from 2011 - 2015.

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 2015.

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

In 2014 we realized that we are finding some non-native, invasive species in significantly more locations around the Great Lakes than are being reported on nonindigenous species tracking websites such as the USGS's Nonindigenous Aquatic Species (NAS) website (http://nas.er.usgs.gov/). Locations of aquatic macroinvertebrates are particularly under-reported. The best example of the difference is shown in Figures 6 and 7 for the faucet snail, *Bithynia tentaculata*. Figure 6 shows the range portrayed on the USGS website for this snail before we reported our findings. Figure 7 shows the locations where our crew found this snail. Finally, Figure 8 shows the USGS website map after it was updated with our crews' reported findings.

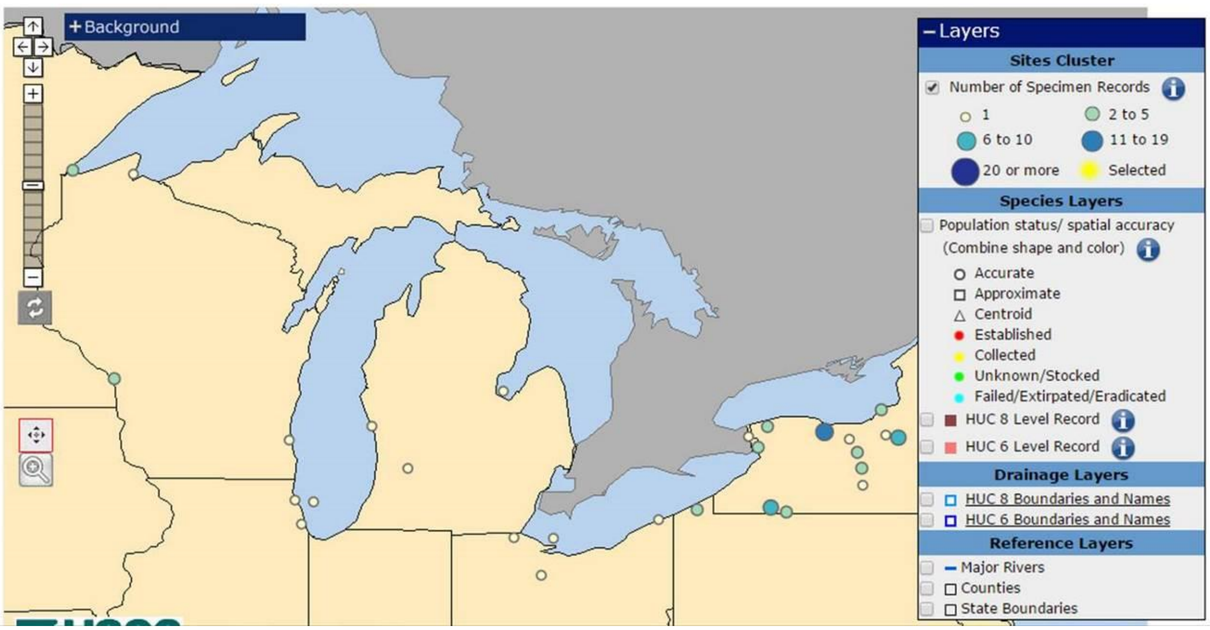

Figure 6. Locations of *Bithynia tentaculata* in USGS NAS website PRIOR to our project providing additional locations where they were collected.

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.

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).

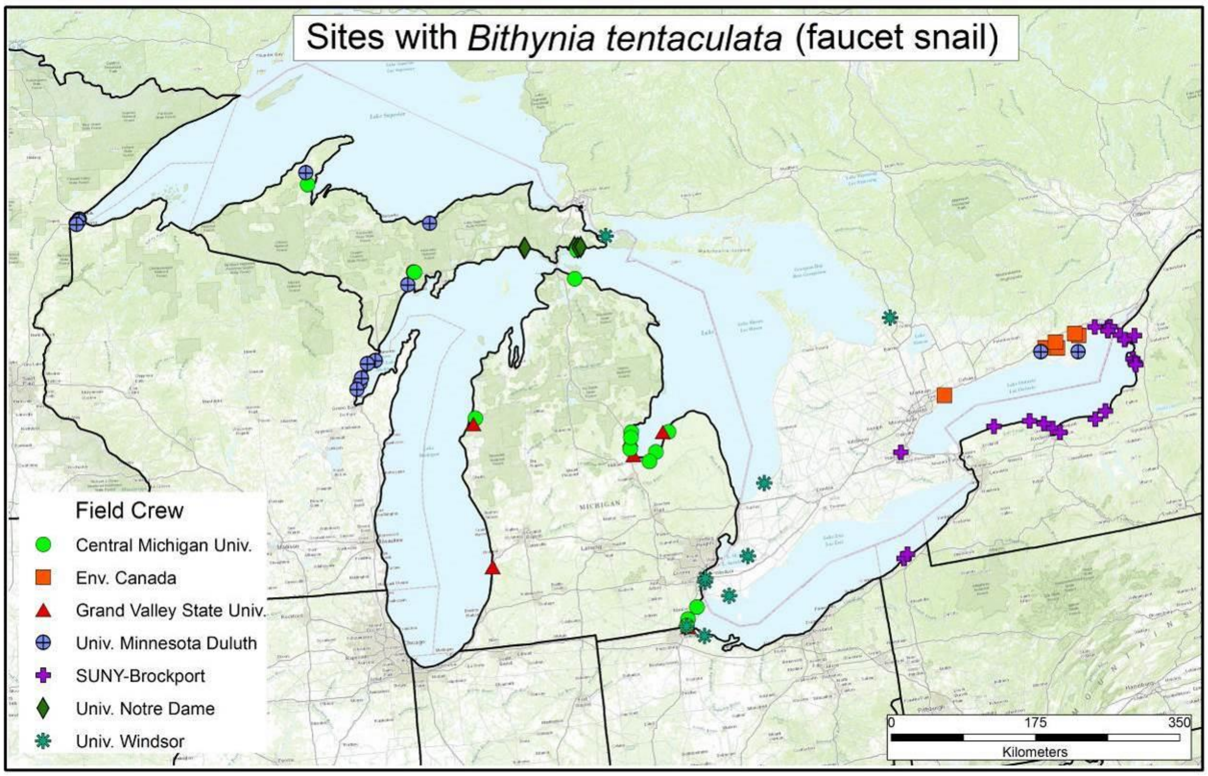

Figure 7. Locations of *Bithynia tentaculata* found by CWM crews, 2011 - 2013.

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.

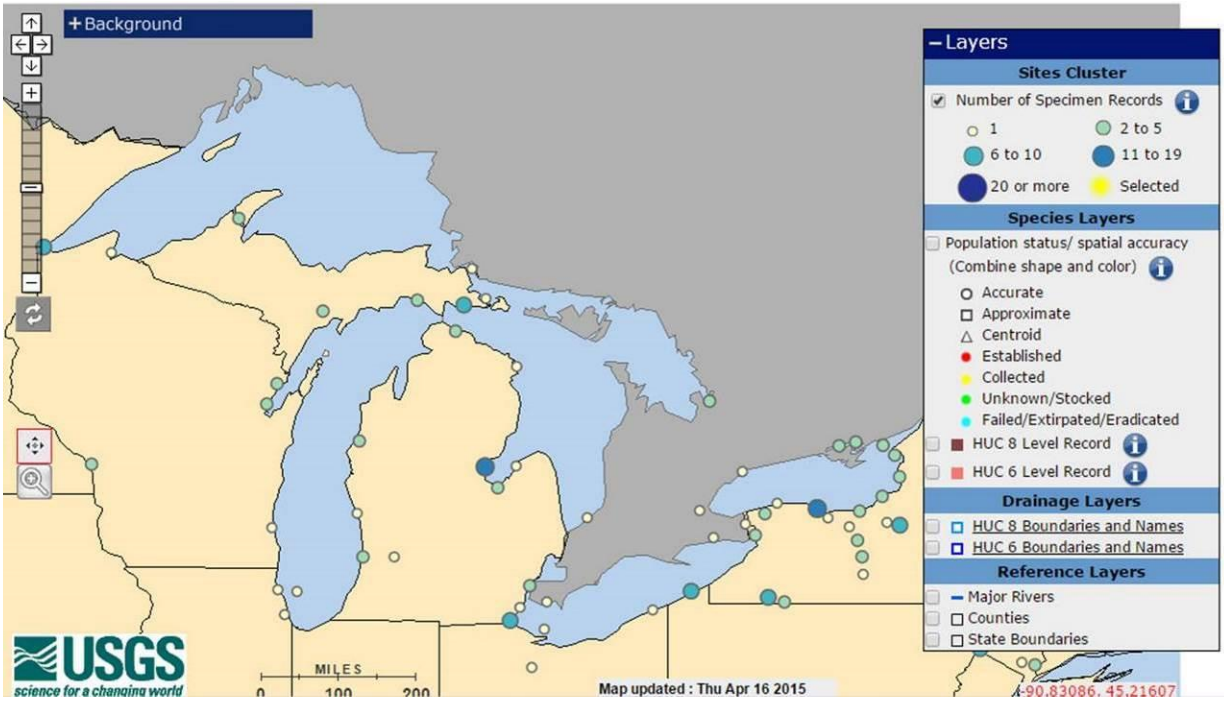

Figure 8. Locations of *Bithynia tentaculata* in USGS NAS website AFTER our project provided additional locations where they were collected; compare to Figure 6.

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 (7-9 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	4.5	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 9). 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.

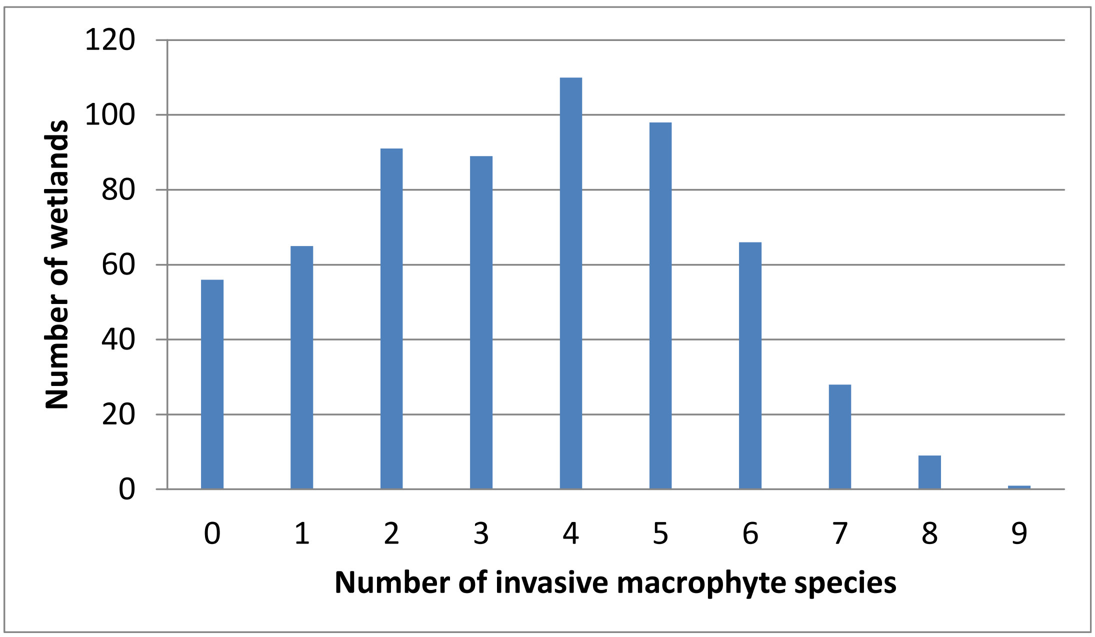

Figure 9. Number of Great Lakes coastal wetlands containing invasive plant species based on 2011 through 2015 data.

As an example for the state of Michigan, we also looked at wetlands with both invasive plants and plant species considered “at risk” (Figure 10). 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.

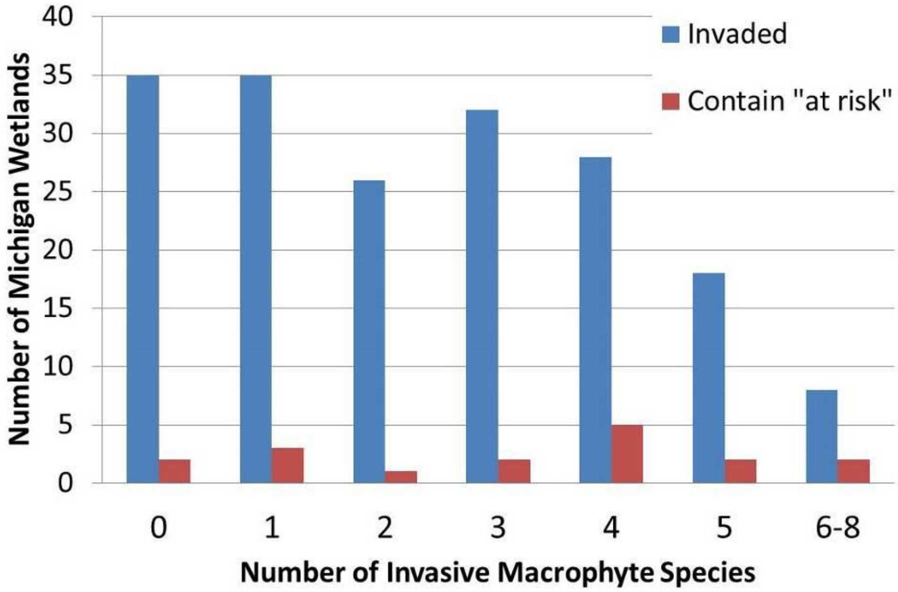

Figure 10. Number of state of Michigan Great Lakes coastal wetlands containing both invasive plant species and “at risk” plant species, based on 2011 through 2014 data.

We created a map of invasion status of Great Lakes coastal wetlands using all invasive species data we have collected so far for all taxonomic groups combined (Figure 11). 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.

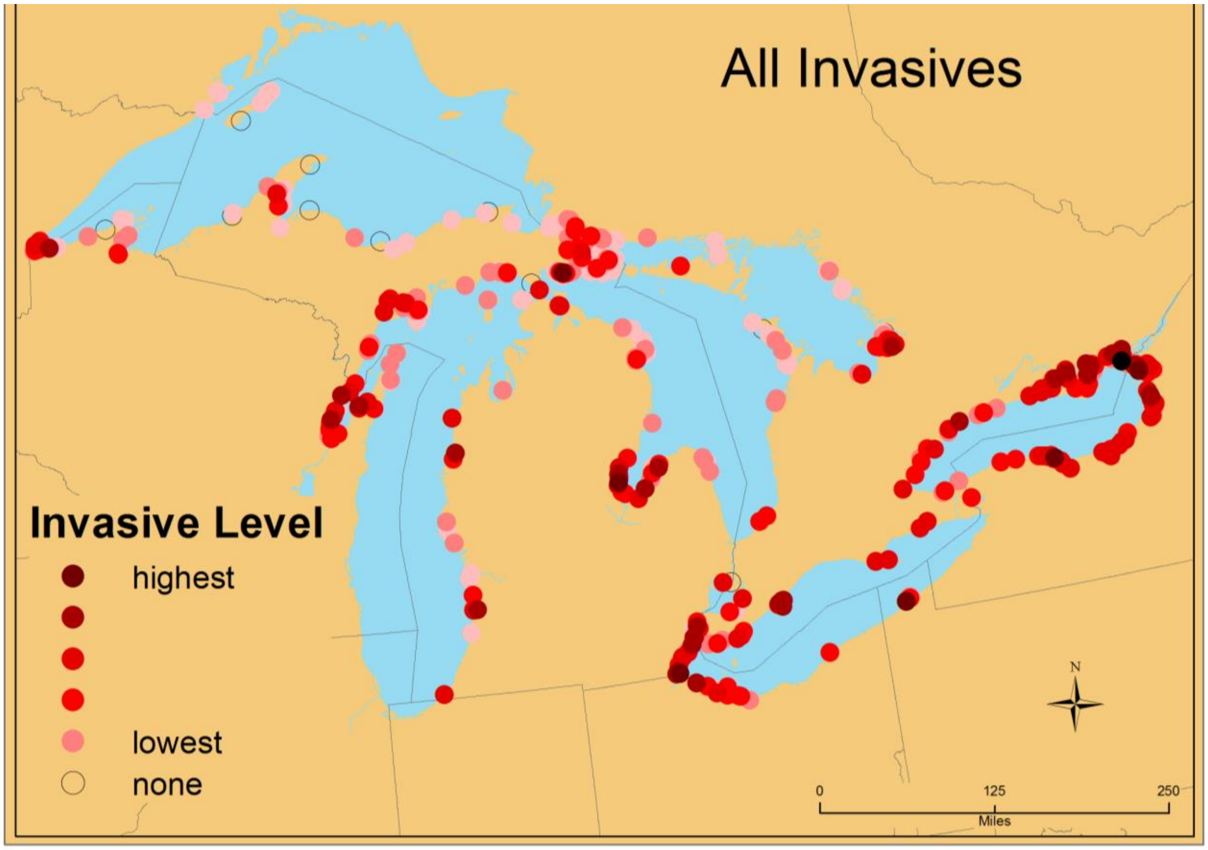

Figure 11. Level of "invadedness" of Great Lakes coastal wetlands for all non-native taxa combined across all taxonomic groups, based on data from 2011-2014.

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 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). 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 12) shows the distribution of Great Lakes coastal wetland vegetation index scores across the basin. Note that there are long stretches of Great Lakes coastline that do not have coastal wetlands due to topography and geology. Sites with low FQI scores are

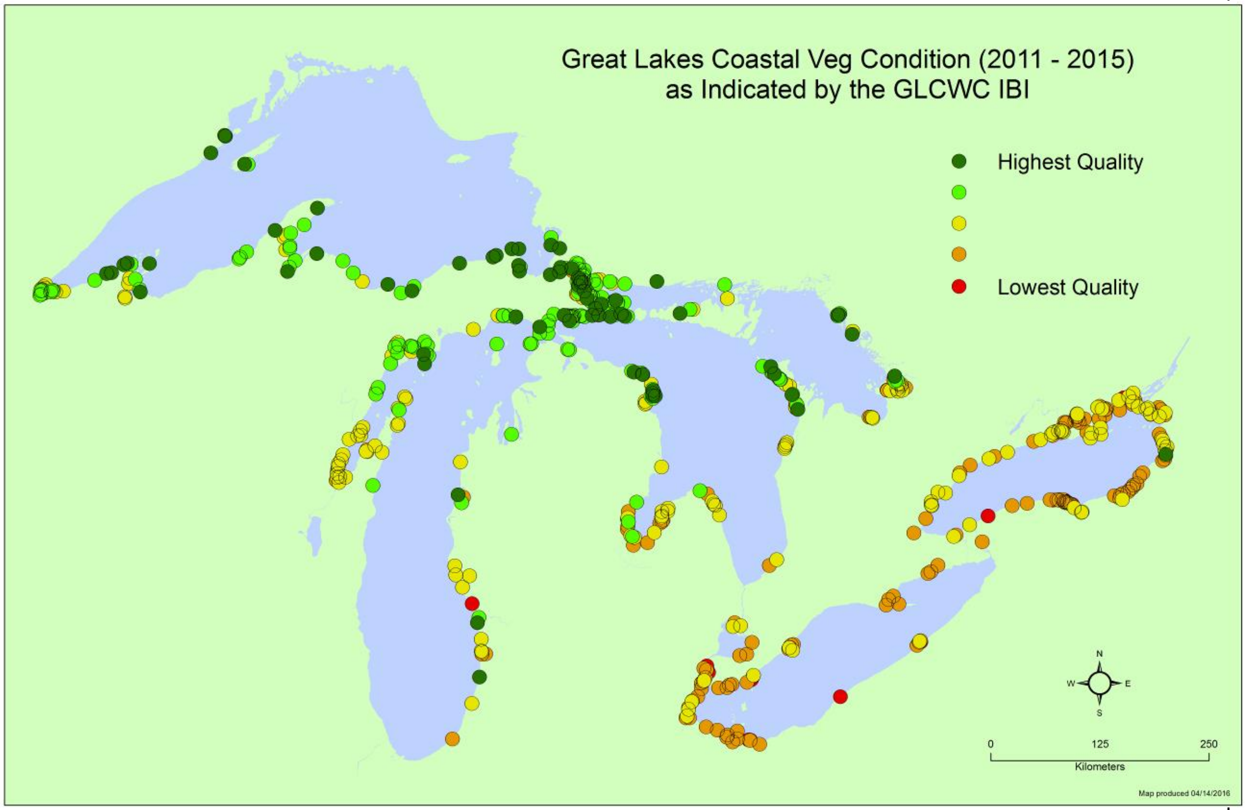

Figure 12. Condition of coastal wetland vegetation at sites across the Great Lakes. Circle color indicates vegetation community quality. The indicator is labeled "draft" while this indicator is investigated for robustness against varying water levels and latitude. Based on data from 2011 through 2015.

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 2015 sites that contain these habitat zones (Figure 13). Minor adjustment of metrics is continuing, so maps are not directly comparable across reports.

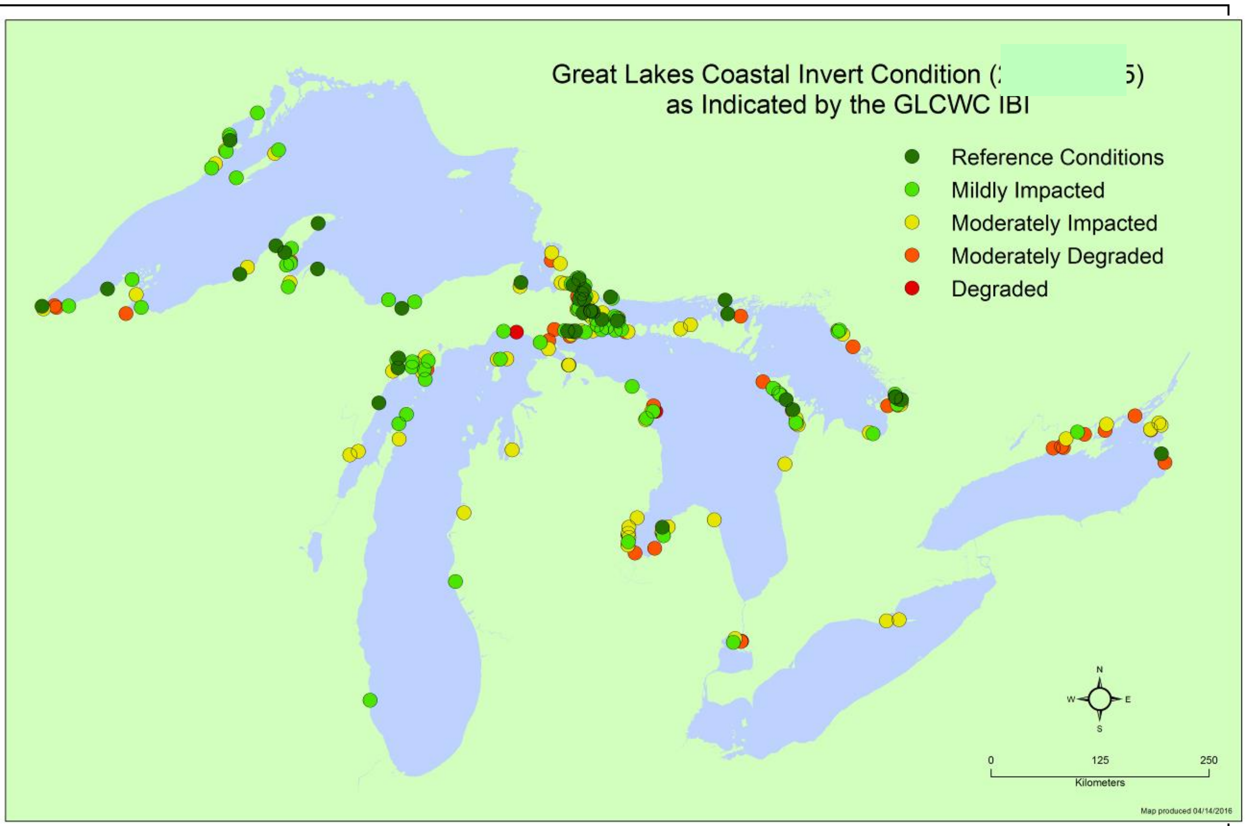

Figure 13. Condition of coastal wetland macroinvertebrate communties at sites with bulrush or wet meadow zones. The indicator is labeled “draft” while more zone IBIs are calculated. Based on data from 2011 through 2015.

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 published macroinvertebrate IBI. We are developing IBIs for additional vegetation zones to cover these sites, but these IBIs have not yet been validated so they are not included here.

We are currently able to report draft fish IBI scores for wetland sites containing bulrush and/or cattail zones (Figure 14). 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.

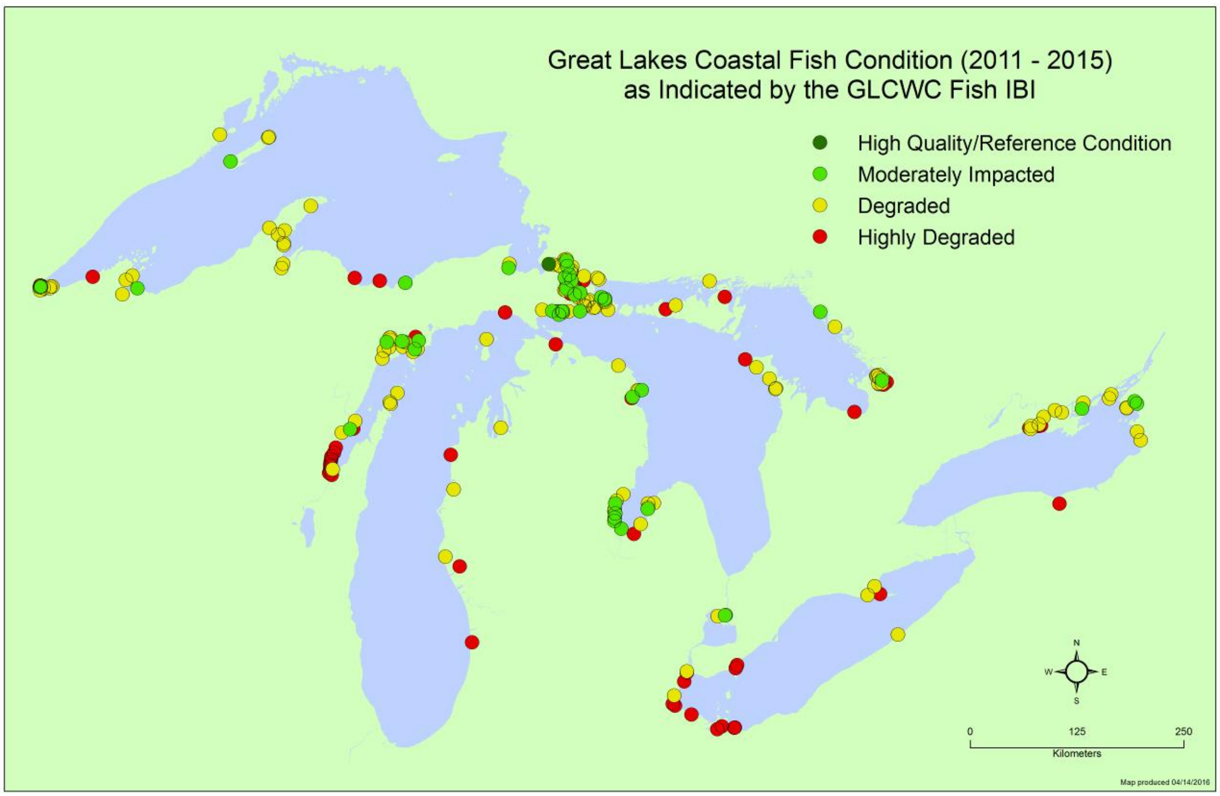

Figure 14. Condition of coastal wetland fish communties at sites with bulrush or cattail zones. The indicator is labeled “draft” while more zone IBIs are developed. Based on data from 2011 through 2015.

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 coasts (Figure 15). 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.

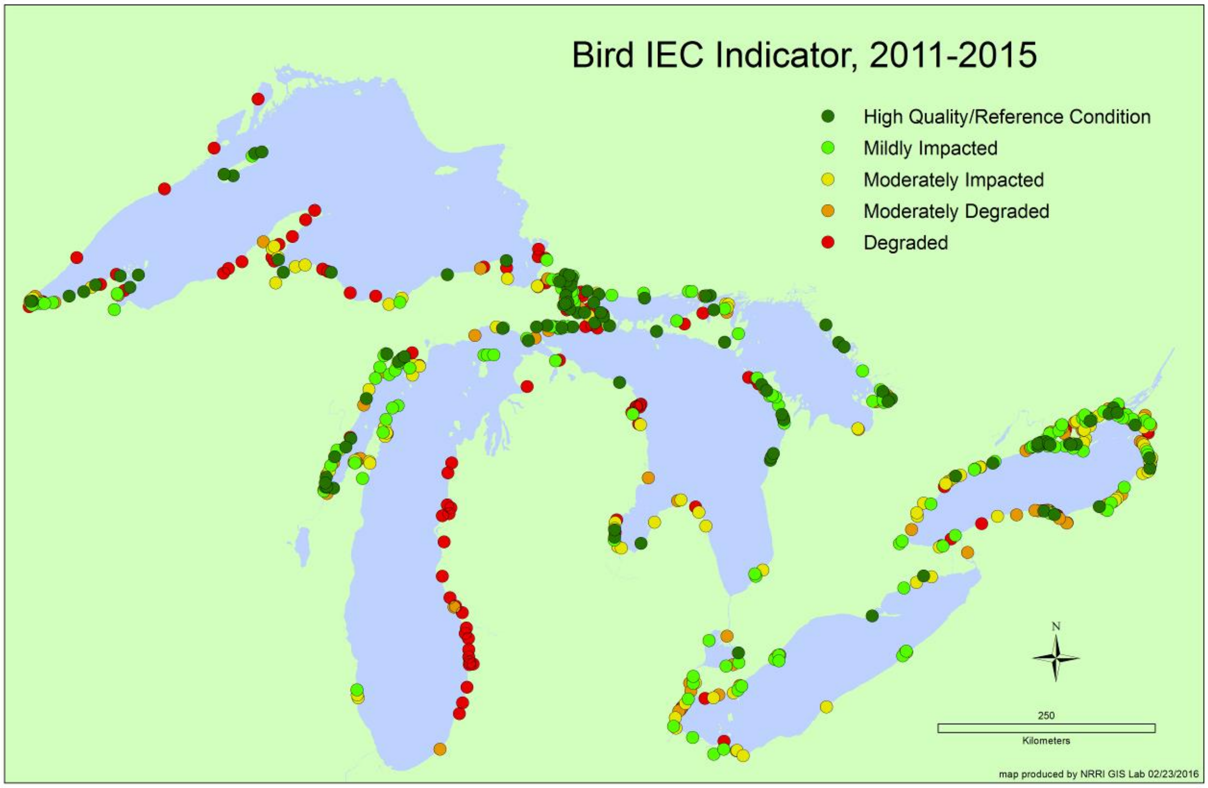

Figure 15. Condition of coastal wetland bird communties. This indicator is based on the IEC method. Based on data from 2011 through 2015.

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 16). 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.

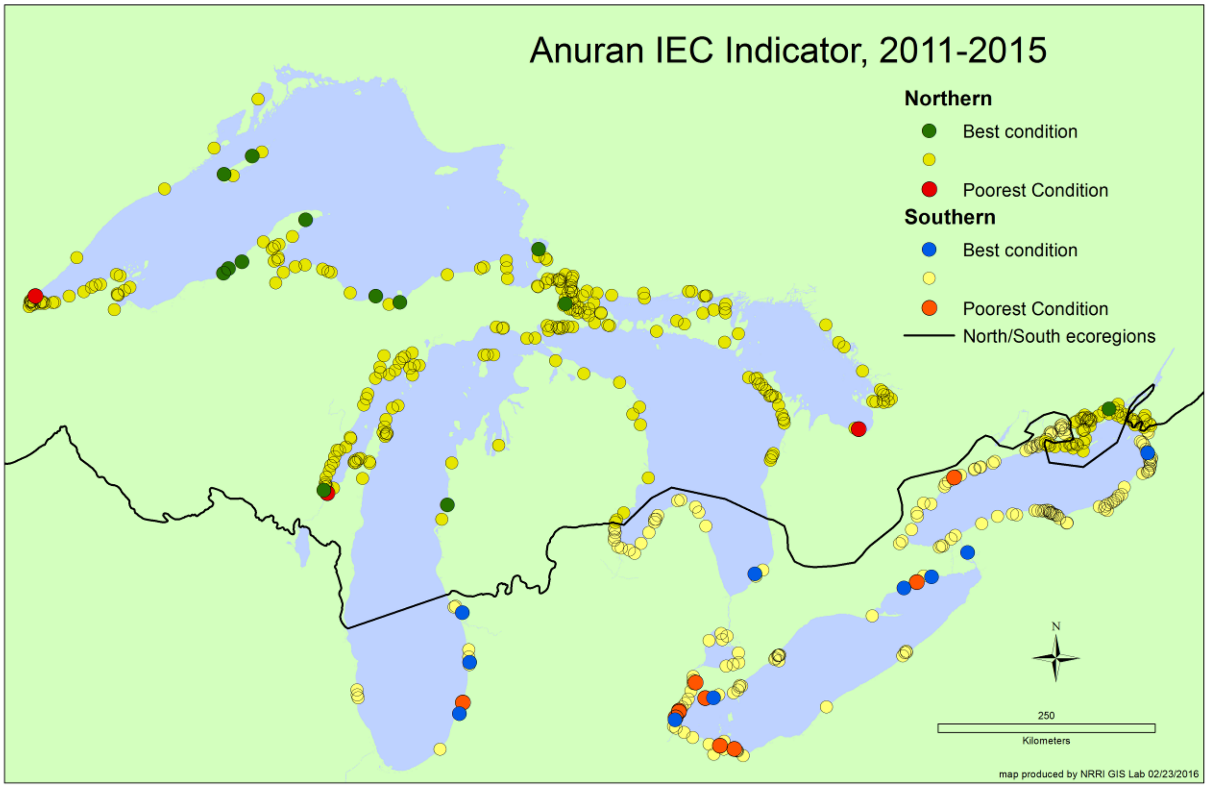

Figure 16. Condition of coastal wetland calling amphibian communties. This indicator is based on the IEC method, and it works best when shown separately for the northern and southern areas of the Great Lakes because of the differences in the amount of agriculture and developed land between these two areas (see text for details). Based on data from 2011 through 2015.

Finally, we have developed a draft disturbance gradient (SumRank) indicator. This indicator is based on landscape stressor data, local stressor data seen at the site itself, and water quality data collected from each aquatic macrophyte plant morphotype (Figure 17). 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 17 inset b.

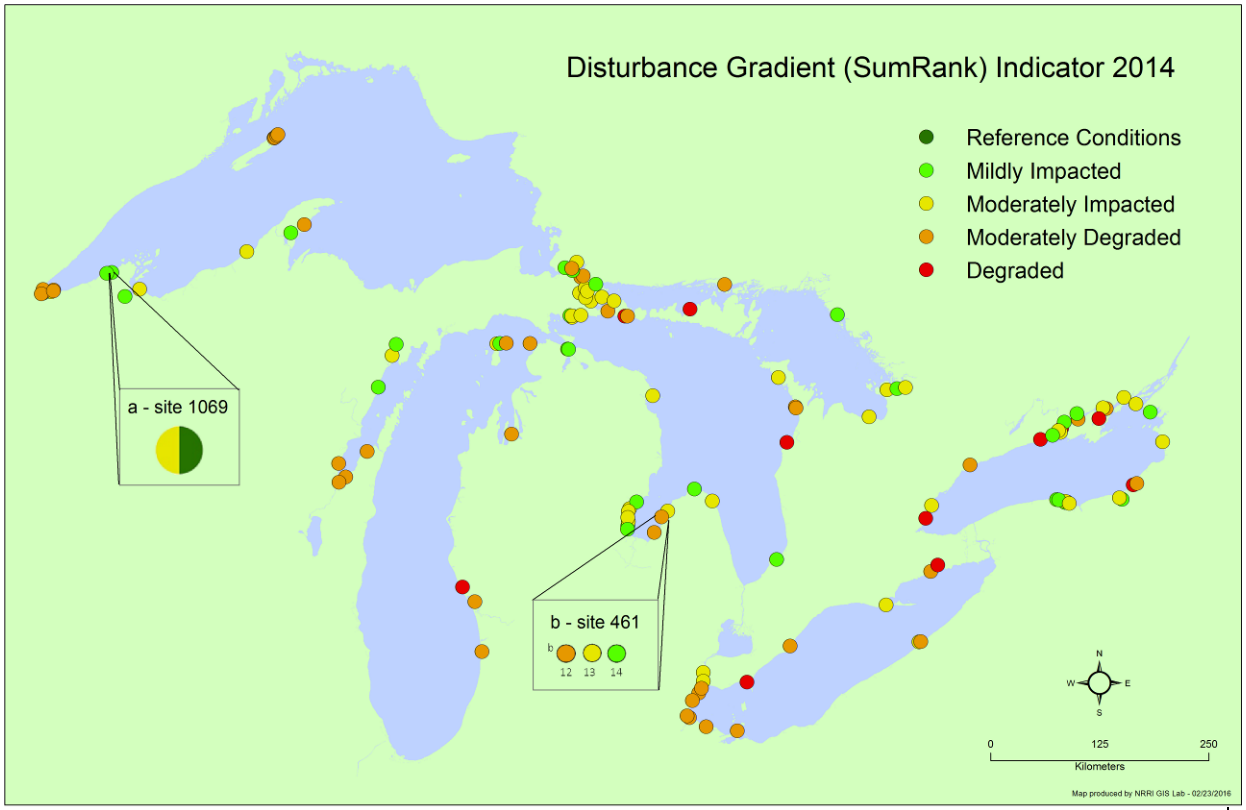

Figure 17. Draft disturbance gradient (SumRank) indicator. This indicator is based on landscape stressor data, site-based stressor data, and site water quality data. This example is based on data from 2014. Wetlands can have different scores for each plant morphotype within them (a), and the indicator may change over time (b).

PUBLIC ACCESS WEBSITE

The Coastal Wetlands Monitoring Program (CWMP) website provides efficient access to program information and summary results for coastal managers, agency personnel, and the interested public (Figure 18). As previously noted, the CWMP website has been redeveloped and upgraded by LimnoTech and transitioned from an NRRI server to a permanent web hosting environment at Central Michigan University. The official launch of the new CWMP website occurred on April 26, 2016, including the public components of the website and data management tools for CWMP principal investigators and collaborators. Since that time, coastal managers and agency personnel have used the new website's account management system to request and obtain accounts that provide access to the wetland site mapping tool, which includes reporting of Index of Biotic Integrity (IBI) scores. CWMP researchers have also obtained new user accounts that provide access to data upload, entry, editing, download, and mapping tools. LimnoTech is 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.

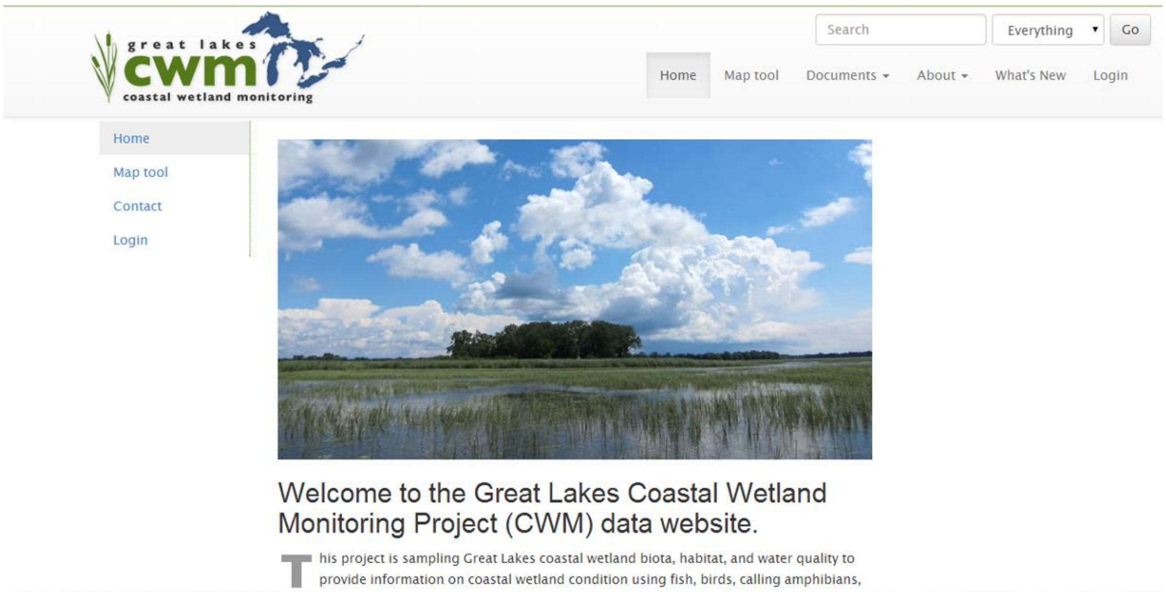

Figure 18. Front page of the new Great Lakes Coastal Wetland Monitoring public website, www.greatlakeswetlands.org.

The CWMP website provides a suite of interrelated webpages and associated tools that allow varying levels of access to results generated by the CWMP, 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 CWMP 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 CWMP 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 CWMP 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 reports & publications (Figure 19; http://www.greatlakeswetlands.org/Reports-Publications);
- CWMP sampling protocols (http://www.greatlakeswetlands.org/Sampling-protocols);
- 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).

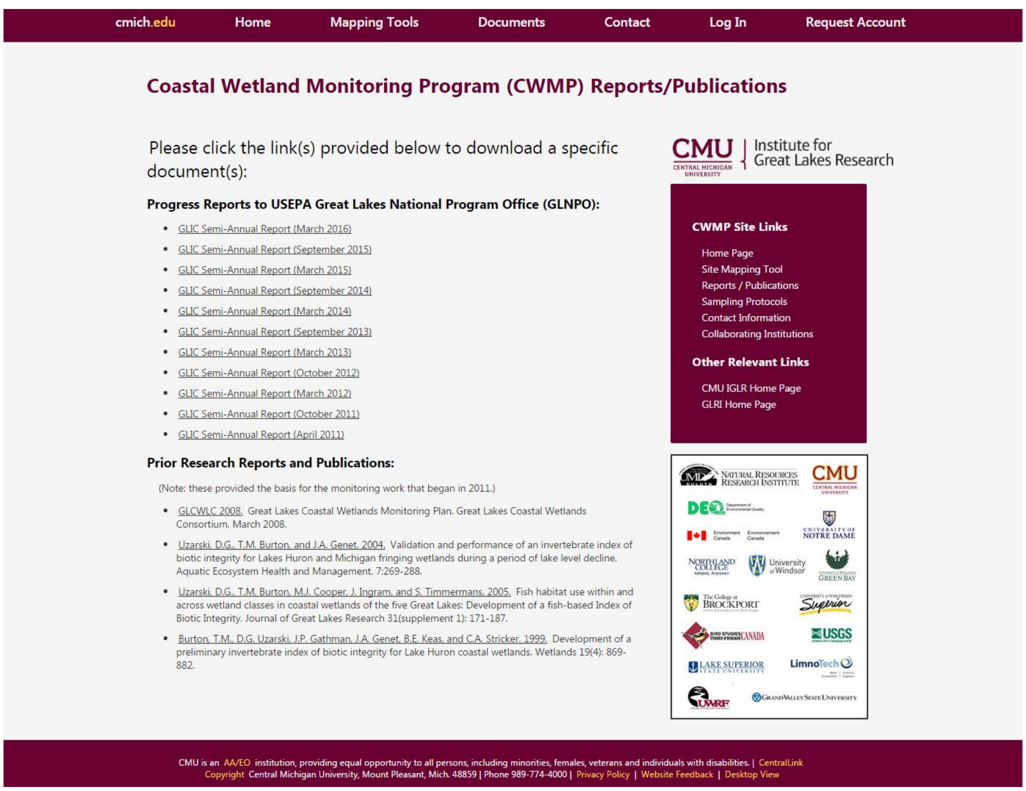

Figure 19. CWMP Reports and Publications Page.

The “Reports & Publication” page provides links to PDF and Microsoft Word documents for program reports and publications, and the “Sampling Protocols” page provides access to 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, Dr. Cooper, and Dr. T. Kevin O’Donnell of the Great Lakes National Program Office (GLNPO).

Coastal Wetland Mapping Tool

The enhanced CWMP 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 20):

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

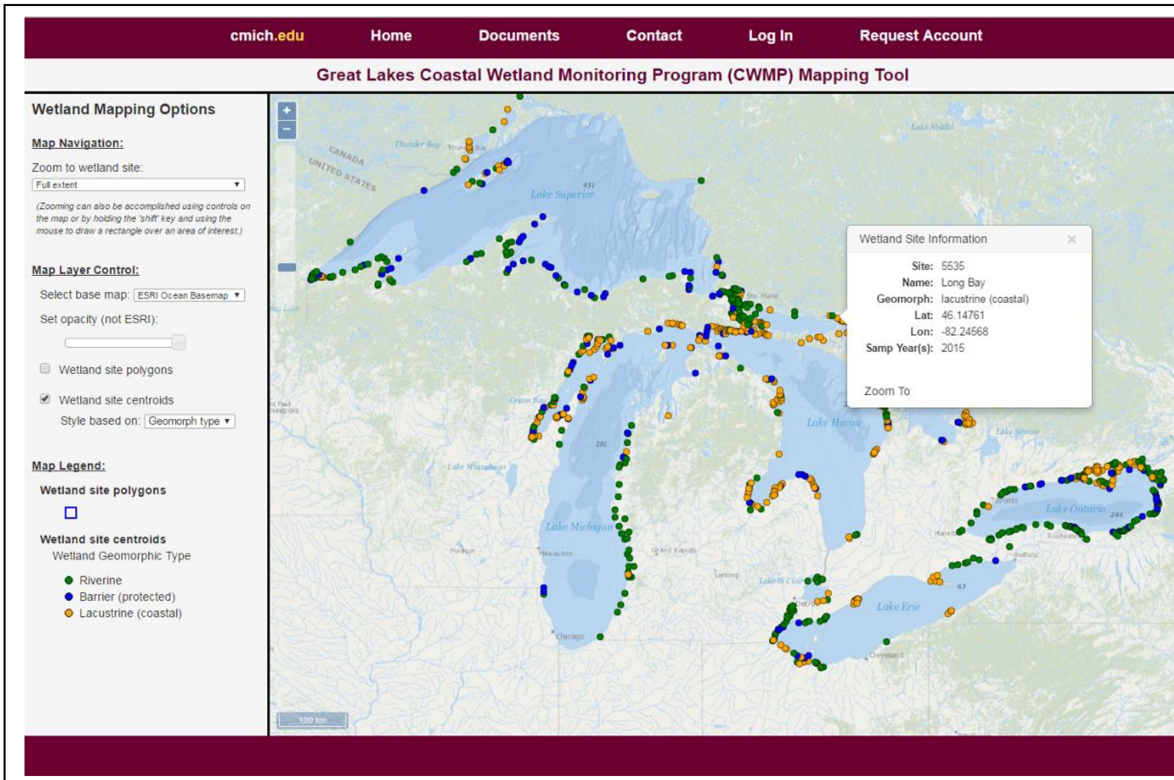

Figure 20. Coastal Wetland Mapping Tool – Public Version (geomorphic type view).

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).

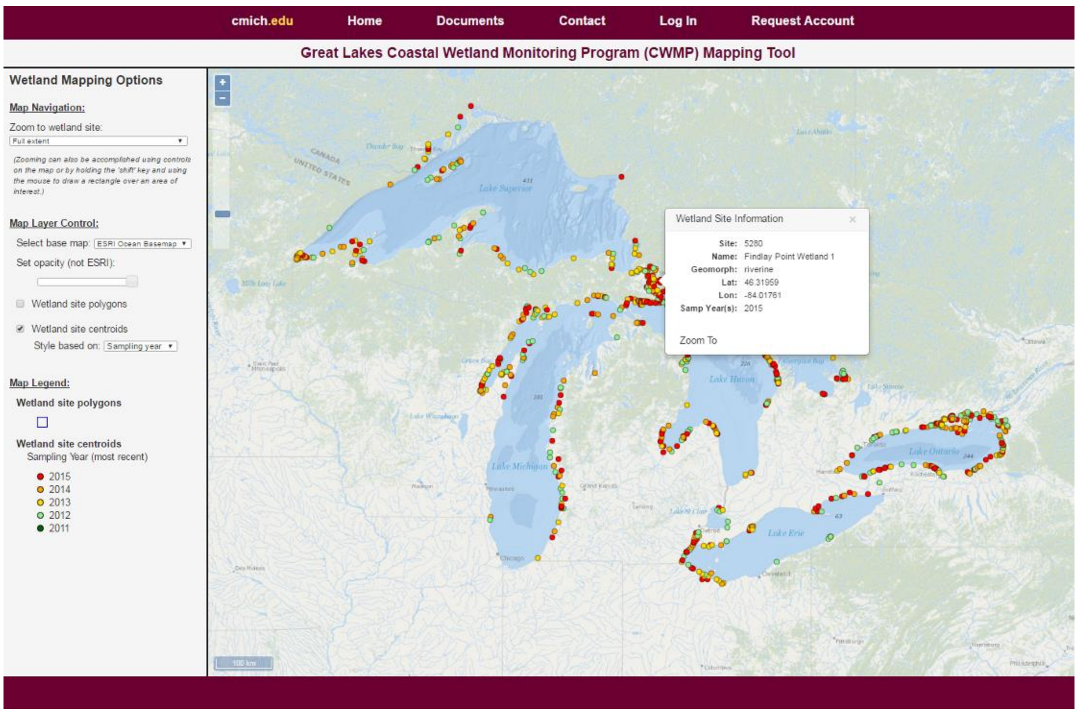

Figure 21. Coastal Wetland Mapping Tool – Public Version (sampling year view)

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

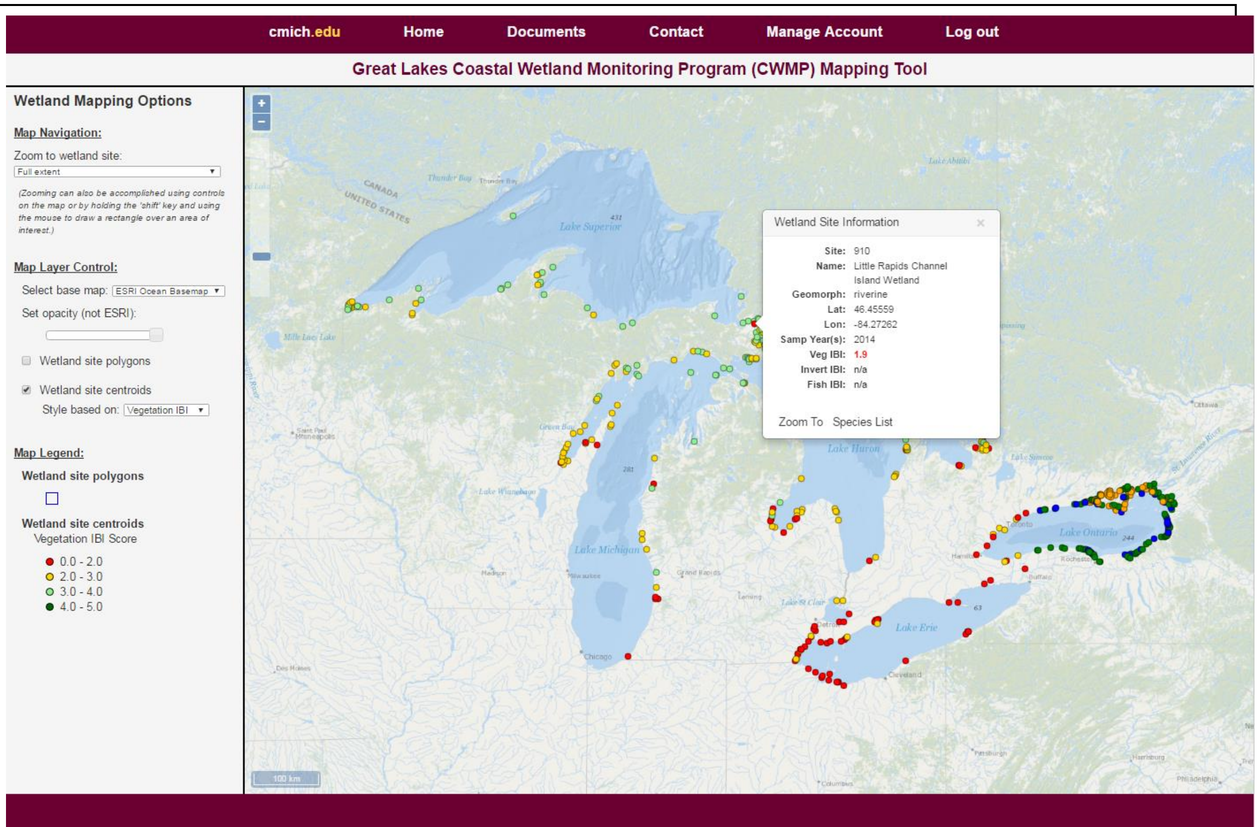

Figure 22. Coastal Wetland Mapping tool displaying the wetland macrophyte IBI scores.

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

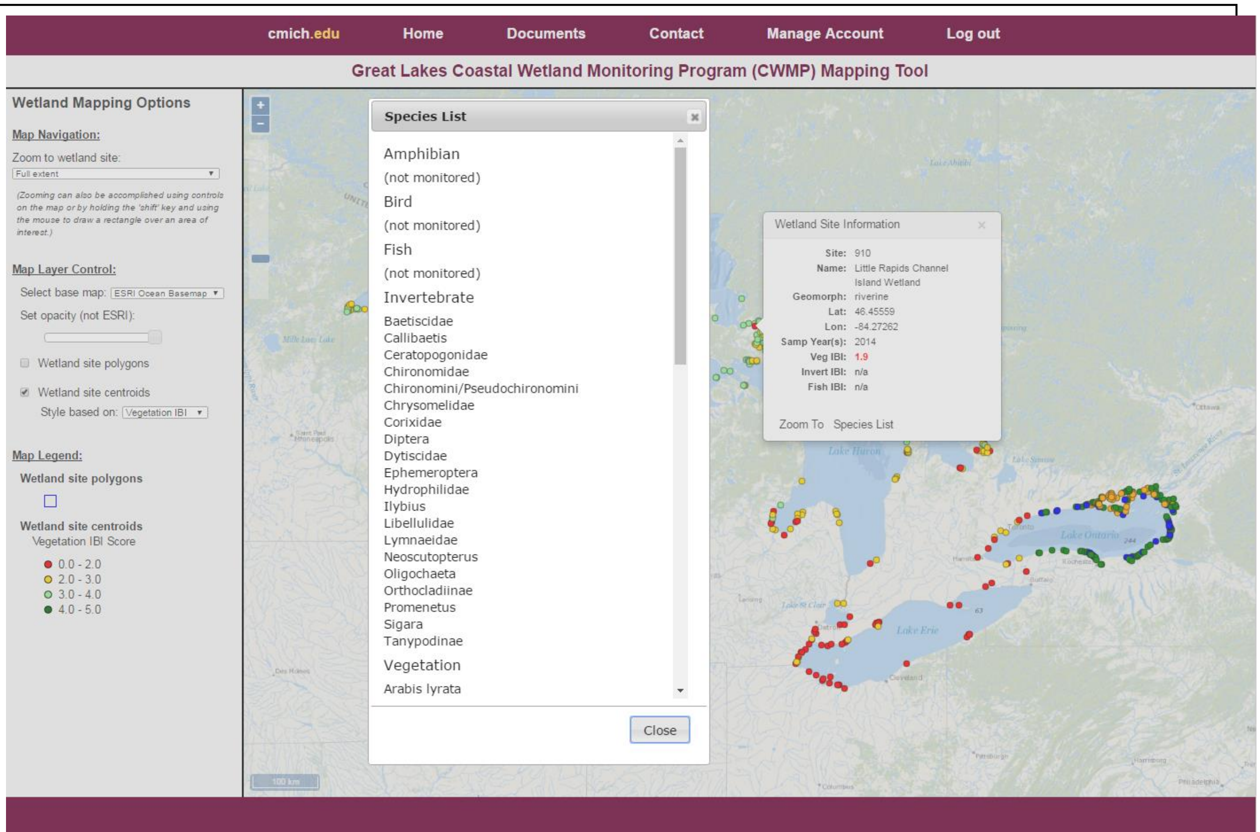

Figure 23. Coastal Wetland Mapping tool displaying the wetland macrophyte IBI scores along with species lists.

Outreach to Managers

In late summer 2016 the Michigan DEQ hosted two full-day information and outreach meetings in Traverse City, MI and Bay City, MI, in order to introduce and promote use of the GLCWM project results through the new GIS-based website and database. The Traverse City meeting was held on August 29, 2016 and was attended by approximately 17 target users from conservation organizations, watershed groups, CISMAs, local government, and state agencies. The Bay City meeting was held on August 31, 2016 and was attended in person by approximately 25 target users primarily from state agencies, CISMAs, and conservation organizations, and had three attendees via webinar from state and federal agencies.

Overall we received very positive responses to these meetings, and the survey responses highlighted some different perspectives. The two meetings were very different, with different backgrounds in the participants, which was reflected in the survey responses. Some of the main comments, both in the survey responses and at the meetings, revolved around interpretation of the information by users accessing the website who are not involved in the project. In particular, many people commented that after seeing the presentations about the monitoring techniques, as well as some of the presentation discussion of how things like water levels or local issues can affect the samples, they had a better understanding of how to interpret the results and of the limitations of this information. Many people were supportive of website improvements to provide more of this information to users online, and they were excited to hear about the decision support tool, currently under development.

Since these meetings we have had many of the participants and their colleagues register for access accounts on the website, at appropriate access levels. We have also had some interest in additional future meetings or webinars on the project, results, and how to access the information through the website.

We are continuing to work on improvements to the website which will assist external users with accessing and understanding the results. We are also planning future meetings and webinars to facilitate outreach and communication to other target user groups throughout the Great Lakes basin, and to encourage use of the website in wetland management and restoration planning and monitoring.

TEAM REPORTS

WESTERN REGIONAL TEAM: **Jerry Niemi and Alexis Grinde (birds and amphibians), Valerie Brady and Lucinda Johnson (fish and macroinvertebrates), Nicholas Danz (aquatic vegetation), and Rich Axler (water quality)**

Field Training

Birds and Amphibians
Training for amphibian surveys was held on 6 April 2017 and bird crew training took place on 25 & 26 May 2017. Training involved 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 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 online system established at the University of Wisconsin, Green Bay – see http://www.birdercertification.org/GreatLakesCoastal - prior to conducting surveys.

Fish, Macroinvertebrates, Vegetation, and Water Quality
Fish, macroinvertebrate, and water quality sampling training was in Green Bay, Wisconsin at the end of June/early July. Most fish/invertebrate/water quality crew members returned from previous seasons, but we were joined by a technician working with Matt Cooper at Northland College and an EPA ORISE fellow; both participated in all aspects of training and site sampling. As has been true the past couple of years, the vegetation crew included a contract botanist who helped sample sites in the UP and northern Lake Michigan. All field technicians were trained in and tested on all standard procedures, including a field-based fish or vegetation identification exam (depending on the crew). Training for all crews included 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 took place in the field at a typical coastal site to ensure field members learned (or reviewed) appropriate techniques. Safety training covered aspects of field safety including safe boating; protection against the elements, animals, insects, and plants; and corrective actions taken when things go wrong.

Sampling permits were obtained from state fisheries management agencies, parks, and various other entities (the states of Minnesota, Wisconsin, and Michigan, the National Park Service, and various state parks). The US Forest Service renewed their decision that no special permits are necessary for any sampling on their lands across the Great Lakes states. We have renewed our University of Minnesota Institutional Animal Care and Use Committee permit for fish sampling.

Site selection

Birds and Amphibians
In 2017, a total of 49 sites were initially selected to be surveyed for birds and amphibians by the Niemi team. Although all of these sites had been surveyed at least once during the 2011-2015 study period by at least one taxonomic group, we still needed to determine accessibility and site conditions which may have changed during this time period (e.g., property ownership, water levels). Of these 49 sites, 13 sites were rejected for bird surveys and 22 sites were rejected for amphibian surveys either prior to visiting the wetland (web reject) or following reconnaissance visits to each remaining site (visit reject). All of the rejected sites for birds and amphibians were due to accessibility issues. Almost all of these sites had been previously rejected in 2011 by bird and amphibian crews for the same reason. The taxonomic groups that did survey these sites used boats, which was not possible or in the sampling protocol for both early morning (bird) and late evening (amphibian) surveys for safety reasons. Amphibian crews were able to sample sites in northern Lake Huron beginning 19 April and bird surveys began 26 May. Sampling was completed by 09 July 2016 for birds and 10 July 2016 for amphibians.

The 36 sites that were sampled by bird and amphibian field crews stretched from the Duluth-Superior harbor area both northeast along the shore of Lake Superior into Ontario 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 2017, we were able to sample a number of island sites for birds and amphibians, including site 1044 (Big Bay Lagoon Wetland) and benchmark site 1046 (Bog Lake Wetland) on Madeline Island, WI; site 942 (Grand Island Harbor Area Wetland #1) on Grand Island, MI; and sites 5333 (Freer Point) and 5957 (Strawberry Channel (West Shore 1) and on Manitoulin Island, ONT. Sites 1117 (Grace Harbor Wetland #1) and 1118 (Grace Harbor Wetland) on Isle Royale were surveyed for birds only. We also surveyed eight island sites in the Apostle Islands National Lakeshore. The majority of the benchmark sites our team surveyed in 2017 were located in the St. Louis River estuary. Of the 13 benchmark sites surveyed in the St. Louis River, seven were island sites. Many of these sites are in some stage of planning for restoration work. Restoration activities for these 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 (see attached letters of support).

Fish, Macroinvertebrates, Vegetation and Water Quality
Fish/macroinvertebrate and vegetation crews ended up with 24 sites after accounting for over-capacity sites, special request benchmarks, and taking on sites for neighboring teams to help them out. Of these sites, fish and invertebrate crews sampled 21 sites (vegetation crews sampled 24 sites) on lakes Superior (12 wetlands) and Michigan (9 wetlands). Three "Benchmark" sites were sampled: 1089, 1098, and 1077, which are all located within the St. Louis River Estuary Area of Concern (AOC). The St. Louis River AOC is a boundary water shared by Wisconsin and Minnesota, and is listed as an AOC due to several beneficial use impairments related to contamination and degraded habitat for wildlife. Water levels were still high in Lake Michigan compared to 5 years ago, and datasheet notes often referred to some zone types (e.g. SAV) as being too deep to sample. On the other hand, zones that in previous years were too shallow to fish were possible to sample with fyke nets this year (e.g. wet meadow). Overall, 46 vegetation zones were sampled for invertebrates, and 30 vegetation zones were sampled for fish. The Northland College fish/invertebrate/water quality crew sampled an additional 2 sites on the Bayfield Peninsula of WI (1039 and 1070), both of which were benchmark wetlands.

Field sampling and preliminary interesting findings

Birds and Amphibians
The sites sampled in 2017 were visited up to four times between 19 April and 10 July. At each site, three surveys were conducted for amphibians and two surveys were completed for birds, one of which was conducted on the same evening as one of the amphibian surveys. Sites surveyed for both amphibians and birds were visited a total of four times, while sites surveyed only for birds were visited twice.

Amphibians
In 2017, a total of seven species were recorded throughout our study sites, with 814 individuals and 124 full choruses counted (Table 14). The average number of individuals recorded per site

visit was 11. The average number of species detected per wetland was 3.7 with a minimum of one and a maximum of six. There was only one site with eight species recorded, site 5106: Blind River 1, a riverine wetland on the north shore of Lake Huron in Blind River, ONT.

Spring peepers (*Pseudoacris crucifer*) were the most abundant species observed in all wetlands sampled, accounting for over a 44% of the amphibian observations and the majority of full chorus observations (Table 14). Neither bullfrogs (*Rana catesbeiana*), which are regarded as an invasive species in the Great Lakes region, nor Mink Frogs (*Rana septentrionalis*) were observed this year.

Table 14. List of amphibians recorded during 2017 surveys. The number of individuals counted and the number of full choruses observed (# of individuals cannot be estimated) are provided for each species.

Species	**Number of Individuals**	**Number of Observations (Full Chorus)**
American toad (*Bufo americanus*)	81	2
Blanchard's cricket frog (*Acris crepitans blanchardi*)	0	0
Bullfrog (*Rana catesbeiana)*	0	0
Chorus frog (western/ boreal –*P.triseriata & P.maculatas*)	1	0
Green frog (*Rana clamitansmelanota*)	150	13
Gray treefrog (*Hyla versicolor*)	160	11
Mink frog (*Rana septentrionalis*)	0	0
Northern leopard frog (*Rana pipiens*)	22	0
Spring peeper (*Pseudoacris crucifer*)	364	96
Wood frog (*Rana sylvatica*)	36	2
Total	**814**	**124**

Birds

In the Western Great Lakes region there have been many observations of birds of special concern in the vicinity of the wetlands or using the wetland complexes in 2017 (Table 15). The most noteworthy observations included secretive marsh birds such as American Bittern (*Botaurus lentiginosus*), Least Bittern (*Ixobrychus exilis*), Virginia Rail (*Rallus limicola*), and Sora Rail (*Porzana carolina*). American Bittern were observed in eight wetlands including four sites in eastern Lake Superior, and four sites in northern Lake Huron. There were three sites with Least Bittern observed, including one site in the Upper Peninsula of Michigan and two sites in northern Lake Huron. There were five sites where Virginia Rails were observed, four of which were in Lake Superior: one on Isle Royale, two benchmark sites in the Superior harbor, and one benchmark site in Wisconsin; the fifth site was located in northern Lake Huron. Sora were observed in four wetlands; one benchmark site in the Duluth-Superior harbor, one in the Upper Peninsula of Michigan, and two in northern Lake Huron.

Eighteen Bald eagles (*Haliaeetus leucocephalus*) were observed at 11 sites. In the Duluth-Superior area alone there are at least four nesting pairs of Bald Eagles; three nests within the St. Louis River estuary and one within 0.5 mi of the shoreline within the city limits of Duluth. Additional species of interest include: Common Loon (*Gavia immer*), which were observed in 10 wetlands; Sandhill Crane (*Grus canadensis*) observed in 7 wetlands; Common Tern *(Sterna hirundo*) observed at three wetland locations in the Duluth-Superior harbor, and Forster's Tern (*Sterna forsteri*) observed at one wetland location in northern Lake Huron.

Table 15. List of birds of special interest recorded during 2017 surveys. The number of individuals observed is listed for each species.

Species	Number of Individuals
Sandhill Crane (*Grus canadensis*)	**24**
Wilson's Snipe (*Gallinago delicata*)	6
Common Tern (*Sterna hirundo*)	9
American Bittern (*Botaurus lentiginosus*)	13
Least Bittern (*Ixobrychus exilis*)	5
Virginia Rail (*Rallus limicola*)	11
Bald Eagle (*Haliaeetus leucocephalus*)	18
Common Loon (*Gavia immer*)	21
Sora Rail (*Porzana carolina*)	6
Great Blue Heron (*Ardea herodias*)	14
Belted Kingfisher (*Megaceryle alcyon*)	10

Birds of special concern were observed in 28 of the 36 wetland sites surveyed in 2017 (Table 15). The lack of observations of Black Tern and Caspian Tern, and the single observation of Forster's Tern, (all species of concern throughout the Great Lakes) is of particular interest and concern.

As in 2016, the bird and amphibian teams included additional vegetation sampling at each of the point count locations. We used the Great Lakes Marsh Monitoring Program's sampling protocol to collect these additional point-level vegetation data within a 100-m circle of each point-count location. Data were collected once at each location during the breeding season. We collected these samples later in the breeding season (during the second round of bird sampling) to insure growth was sufficient to properly estimate vegetation (type and abundance). Details regarding collection of this information can be found in the Great Lakes Marsh Monitoring Program's habitat guidance booklet (Meyer et al. 2006).

Fish and Macroinvertebrates

Some interesting observations occurred at site 1406, which is on Washington Island offshore from the Door County peninsula in Lake Michigan. At site 1406 the NRRI field team encountered high densities of what we believe to be Eastern Newts (*Notophthalmus viridescens*) (Figure 24). They were present as bycatch in nearly every fyke net. Also, within this wetland we observed what were likely Northern Water Snakes (*Nerodia sipedon*) sunning themselves on top of two of our nets. One net actually had a snake within it that we carefully released. The abundance of salamanders and snakes is likely not a coincidence (i.e., the snakes were probably feeding on the amphibians), but it stood out as something atypical to our normal observations of wetland biota.

Figure 24. Eastern Newts were abundant at site 1406.

A handful of sensitive fish species assigned threatened status in Wisconsin were encountered by NRRI during the 2017 field season. At 7033 we collected several Greater Redhorse (*Moxostoma valenciennesi*), which persist in Lake Michigan in relatively low numbers (Figure 25). Greater Redhorse were also captured at site 7033 in the 2016 field season. A Blandings Turtle (*Emydoidea blandingii*) was collected as by-catch in a fyke net at site 1698 (Figure 26). Blanding's Turtles are listed as a species of special concern in Wisconsin, due in part that it takes 17 to 20 years for individuals to reach maturity. Some other interesting fish catches were a young-of-the-year Rainbow Trout (*Oncorhynchus mykiss*) captured in a sparse bulrush vegetation zone within a Canadian Lake Superior wetland (site 5305), and a juvenile Cisco (*Coregonus artedi*) captured within a Lake Michigan wetland (site 1678). Rainbow Trout and Cisco are not rare species in Lakes Superior or Michigan, but they are uncommon to collect in wetland samples because they are typically off-shore species.

Figure 25. Greater Redhorse, a threatened species in WI, captured at site 7033.

While we encountered a few rare fish, we also observed several invasive species during 2017 fish surveys. Invasive fish or crayfish were present at 15 of the 19 fished sites. Round Goby and Common Carp were the most frequently detected, and other invasive fish identified were Alewife, Sea Lamprey, and Tubenose Goby. Non-native Three-spine Stickleback were observed at 4 sites in 2017, which is more than we usually find in a typical summer. The NRRI crew collected rusty crayfish at just one site: 1406.

Other Activities: The Great Lakes Coastal Wetland Monitoring Program led to a spin-off functional assessment project funded by USGS, which started in the fall of 2016 and continued through the spring and into fall of 2017. Six GLCWMP wetlands are getting additional surveys in 2017 (sites 1077, 1098, 1457, 1698, and 1703). Fish, invertebrate, and water chemistry survey methods for the USGS functional assessment project are similar to GLCWMP standard surveys, but other surveys were omitted (i.e. no bird, amphibian, or macrophyte sampling). Up to 10 juvenile fish of each species encountered were preserved and sent to USGS for diet analysis.

Data requests: Dr. Alice Yeates requested an invertebrate and fish taxonomy list for Pokegama Bay (site 1096) to inform the development of an aquatic wildlife mural at the Lake Superior National Estuarine Research Reserve (LS NERR). Information about the Reserve, including their mission statement, can be found at https://lakesuperiorreserve.org/

Figure 26. Blandings Turtle collected at site 1698 by the NRRI field crew in 2017.

Aquatic Vegetation

In 2017, water levels were again very high in wet meadow and emergent zones. While the influences of increased water level on vegetation have yet to be addressed with data analysis, anecdotally it seems that many forb species commonly found in wet meadow zones have decreased in abundance throughout the study region as water levels have risen. Crews have also noticed shrubbier and treed wetlands are experiencing mortality of these woody plants, with several areas of standing dead stems visibly apparent.

2017 Sample Processing, Data Entry, and QC

All data entry and QC for birds and amphibians was completed (100%) during August-September 2017. Data entry and QC for fish, field habitat and water quality will be done over the winter. In addition, macroinvertebrate ID and data entry will be completed over the winter. Field data for aquatic macrophytes were entered into the project database by early-September and have been subjected to QA/QC procedures. The PIs conducted mid-season checks by visiting a few sites and verifying that proper protocol was being implemented.

Metrics and Indicator Calculations

In Spring 2017, PI Danz used data 2011-2016 to evaluate temporal variability in one indicator of wetland plant quality, Mean C. Based on analysis of 708 surveys on 547 unique sites, Mean C was found to be relatively stable from year to year at both sites (Figure 27) and across entire lakes (Figure 28). Sites typically had highly correlated Mean C scores in consecutive years. On average, the absolute difference in Mean C for sites surveyed in consecutive years was 0.48, which translated to a 15% average change. For sites surveyed with a 5-year interval, the average difference in Mean C was 0.78, or a 28% change. For individual sites, statistical power analysis showed there would be a required year-wise difference in Mean C of about 1.0 to translate to a statistically significant change.

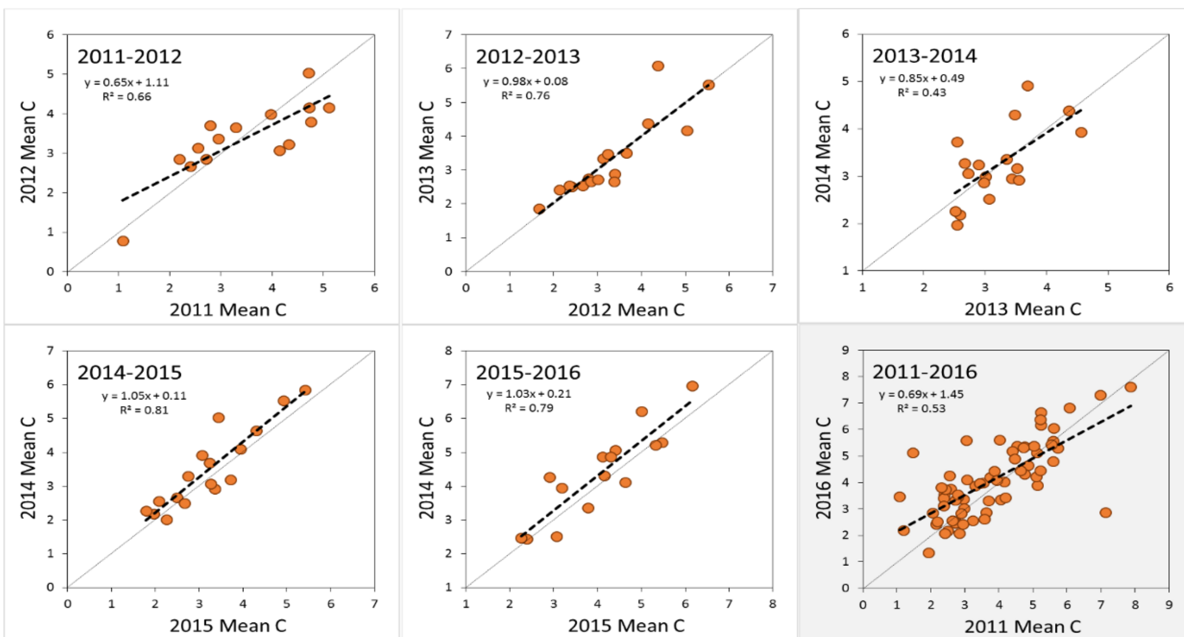

Figure 27. Patterns of change in Mean C for sites sampled in consecutive years and with a 5-y interval. Different subsets of sites were surveyed in each year-pair.

Averaging across entire lakes, the highest annual average change in Mean C ranged from 0.16 (Lake Michigan) to 0.34 (Lake Ontario). Aquatic vegetation PIs will be working in the future to determine statistical power analysis for these intermediate-term trends in Mean C seen in individual lakes.

Throughout summer and fall 2017, Danz used data from this CWM project to help prioritize wetland sites for restoration in the Lake Superior basin. This work, in collaboration with Cherie Hagen (WIDNR) and others, is ongoing. Currently, we are researching historic records of vegetation composition throughout the St. Louis River estuary and other WI coastal wetlands to determine if current wetland quality, as judged by our surveys, has experienced substantial recent declines. PIs on the vegetation project have been working to analyze temporal patterns in floristic quality metrics (e.g. mean Coefficient of Conservatism, FQI). We are asking 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, as we are now seeing. Moreover, 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.

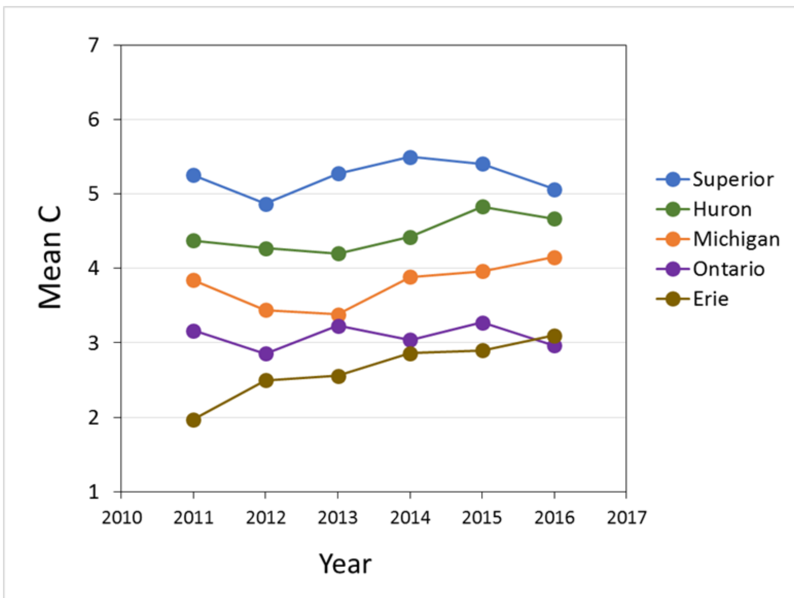

Figure 28. Average Mean C per year for individual Lakes. Measures of precision are not shown to preserve figure clarity.

Central Basin Regional Team: Don Uzarski (water quality and macroinvertebrates), Thomas Gehring and Robert Howe (birds and amphibians), Carl Ruetz and Ashley Moerke (fish), Gary Lamberti (macroinvertebrates)

CENTRAL MICHIGAN UNIVERSITY

Fish/Invertebrate/Water Quality Crew

Field sampling began June 27th, 2017, and was completed on August 25th, 2017. Central Michigan University was assigned 20 sites. Two were rejected during site visits. Site 1131 within Isle Royale National Park did not have inundated vegetation, instead the vegetation resided mostly on cut banks within the river proper. Site 541 in Thunder Bay did not have zones large enough to sample. In total, 35 zones were sampled for water quality and invertebrates and 24 sites were sampled for fish community.

Site 523, in Saginaw Bay, was used for a Central Basin training event led by CMU this year (Figure 29). Crews from LSSU and GVSU attended along with representatives from the US EPA and CSRA (Courtney Winter, Louis Blume, and Brick Fevold). Training covered protocol for fish, invertebrate and water quality sampling (including *in situ* titration and filtering). Proper zone identification, as well as restrictions on fish and macroinvertebrate sampling were covered in depth. Exceeding maximum depth for fyke net sets was a common incidence across all sites sampled this season. Many sites had zones that were unable to be sampled for fish but were still sampled for water quality and invertebrates.

Weather events were a common obstruction to sampling this field season. As such, sites in the Alpena and Les Cheneaux regions on Lake Huron required revisits later in the field season. Thus, fish, habitat and *in situ* water chemistry data entry has begun, but is still underway. Water nutrient analysis is underway and on schedule. We have received water samples to be analyzed for total nutrients and dissolved nutrients from LSSU and expect those from UND shortly. All water chemistry for the CMU wetlands is expected to be complete and entered by early 2018. All macroinvertebrate identification has been completed and awaits QC. We expect all data entry and QC to be complete by early 2018.

Figure 29. Representatives from EPA-CSRA, and members from the LSSU and GVSU crews attend the Fish/Invertebrate/Water Quality training event led by CMU at site 523 on June 27/28th, 2017.

The crew noticed that more northern sites had new or denser stands of *Phragmites* than previously noted. Specifically, we noticed at St. Ignace a new patch (unsampleable due to size) where the site had previously been uninvaded and denser stands in the Thunder Bay/Alpena area (Figure 30).

<u>Vegetation Crew</u>

PI Dennis Albert trained crew leaders and field assistants in both plant identification and sampling protocol on June 27th and 28th. All crew members passed the exam.

Figure 30. Small stand of *Phragmites* seen at site 1598 (Point St. Ignace) previously not seen at the site.

The Central Michigan University vegetation crew was assigned 51 sites initially. Of those sites, two were web rejected because aerial images showed there was no wetland in the area. Another two sites did not have a direct water connection and were not sampled. Four sites in northern Lake Michigan could not be sampled because they exceeded capacity. Two sites were not accessible. Site 7030 was located in the Illinois Beach State Park Wetland and was not sampled due to difficulties obtaining permits. In total, 40 sites located around Michigan were successfully sampled during the 2017 field season (June 28th-September 16th, 2017). Sites differed in invasive species presence from south to north (Figure 31, 32). *Phragmites* stands were of intermediate size at the mid-latitude to northern sites and were taken for genetic analysis to confirm invasive versus native genotypes.

Figure 31. Site 1913 in Lake Erie with high nutrients and invasive plant species.

Plants that could not be identified in the field or in the Central Michigan Lab were pressed and are being sent to Dennis Albert for identification. As plants are identified the datasheets will be updated and data will be uploaded to the database. All data should be entered by midwinter 2018.

Bird/Amphibian Crew

All 2017 amphibian and bird survey data were uploaded and QC'd in the database. We sampled amphibians and birds in coastal wetlands on lakes bordering the Lower Peninsula of Michigan, eastern Upper Peninsula of Michigan, and sites in western Lake Erie, Ohio during summer 2017. Three teams, each with two members, were used throughout the sampling season. Amphibian and bird training was completed by 6 March 2017 at CMU. Online testing was used for identification of amphibians and birds by sight and sound and all data collectors reached proficiency before sampling. Field crews consisted of undergraduate student technicians and graduate student field crew leaders.

We surveyed 40 wetland sites, of which 7 were benchmark sites. Of the original number of wetlands, we were assigned to sample (n = 48), we web rejected 1 site, and 7 sites were not sampled because they could not be accessed.

Figure 32. Site 1131 on Isle Royale had a higher quality plant community among sites sampled in 2017.

We sampled amphibians during 12 April to 10 July 2017 and birds during 20 May to 10 July 2017. Wetlands were sampled three separate times for amphibians and two separate times for birds.

UNIVERSITY OF NOTRE DAME

Fish/Invertebrate/Water Quality Crew

In mid-February, UND was assigned 10 sites for 2017; however, site 7030 had its polygon altered (adjacent to 1373) and was rejected because it is a perched dune-and-swale wetland. The UND crew retained the same crew leaders for 2017, with only one new undergraduate summer technician to train in CWMP protocols. We visited a nearby benchmark site (Galien River, site 1325) as our training site to walk through the sampling protocols before actually visiting sites for CWMP. Gary Lamberti (UND PI) was able to aid in sampling at multiple sites and verify our fidelity to CWMP sampling protocols.

Starting in mid-June through the first week of August, the UND crew visited 9 sites spread out among the east shore of Lake Michigan and including a pair of sites in Lake St. Clair. As most of our sites were riverine in nature, we sampled as far downstream as feasible based on public access or boat launches. All had apparent hydrologic connections to a Great Lake. We sampled for water quality, fish, and invertebrates in all zones that we found met protocol criteria. UND's crew was also not immune to the higher water levels seen by many collaborators – this altered vegetation distributions and limited fishable zones in some large sites.

Water samples were sent to CMU for analysis, and chlorophyll-*a* samples have been received from most Central Basin partners for UND to analyze. The estimated 6300 macroinvertebrates picked during field sampling have been sorted and identification will be completed in early 2018. Fish unknowns were confirmed in the laboratory and sediment loss-on-ignition analysis has been completed. All field data have been entered into the CWMP database and confirmed by another person.

100% of 2017 field data have been entered; 100% have been QC'd by a second person. 2017 macroinvertebrate samples have yet to be identified. Water nutrient data entry has not yet been completed, but will commence upon analysis and return of all lab samples from CMU.

GRAND VALLEY STATE UNIVERSITY

<u>Fish/Invertebrate/Water Quality Crew</u>

Two new crew members and two returning crew members received hands-on training on the field sampling protocols on 26-27 June 2017 at the training led by CMU in Pinconning, MI. Further training on field sampling protocols was led by crew leader Travis Ellens on 12-13 July 2017 in Puffy Bay (Delta County, MI).

We were able to sample 6 of 8 wetland sites that were assigned to us. All sampling was conducted during July-August 2017. We sampled 14 plant zones at six wetland sites for macroinvertebrates and water quality, and we sampled seven plants zones at four sites for fish, macroinvertebrates, and water quality. All field work for 2017 has been completed. Data entry has been completed for all field site data, water quality data, and fish data. We are in the process of completing data entry and checks for macroinvertebrate and lab water quality samples. Macroinvertebrate identification in the lab will began in October, and we plan to have all macroinvertebrate data entered and checked by early spring 2018. Lab water quality samples have been sent out for processing, and the observations will be entered and checked once completed.

In addition to field work, the Ruetz lab worked on a manuscript summarizing the results of an investigation to evaluate morphological/meristic and genetic (DNA barcoding and microsatellites) techniques for the identification of brown and black bullheads. Ruetz (and GVSU grad student Greg Chorak) have worked extensively with Josh Dumke (University of Minnesota, Duluth) to finalize the manuscript. The manuscript was submitted to the journal *Copeia* and was rejected. The manuscript is being revised and will be submitted to a different journal, which is yet to be determined.

We planned to sample eight wetlands sites during the 2017 field season for fish, macroinvertebrates, and water quality. Our crew visited and rejected two sites due to little or no wetland vegetation present at each site. Two sites could only be sampled for water quality and invertebrates due to safe access issues. Four sites were sampled completely.

Overall, the 2017 sampling season was successful. The sampling period (July-August) coincided with maturation of plants, which made for easier identification of plant zones. On average, it took our crew (4 people) about 10-12 hours in total to finish an entire site. Our main challenges were extended travel, with 75% of our sites in Michigan's upper peninsula, high water levels making it difficult to wade in many areas of each wetland, and above average fish catch in one net at site 1754 (over 2,600 fish). Due to high water levels, we sampled a wet meadow plant zone at 5 out of 6 of our sites sampled. In previous years, sampling of a wet meadow plant zone was uncommon due to lower water levels compared with 2017. Observations while picking macroinvertebrates from wet meadow zones indicate that typically this is a plant zone with an abundant and diverse macroinvertebrate community, and we suspect macroinvertebrate identification and enumeration in the lab will support this observation.

LAKE SUPERIOR STATE UNIVERSITY

Fish/Invertebrate/Water Quality Crew

Crew members were trained and certified in sampling protocols in June, and then the crew along with A. Moerke (LSSU PI) attended the training session offered by CMU in Saginaw Bay in late June. From late June to August, the LSSU crew visited 12 sites to determine if they met the sampling criteria and if there were access issues. Four sites were not sampled based on no evidence of an existing wetland or a Great Lakes connection to the wetland. Crews returned to 8 sites and collected water quality, macroinvertebrate, and fish data and samples (along with other associated measurements) for all vegetation zones identified and that were within the sampleable water depths. Water samples were mailed to Central Michigan University at the end of August for dissolved nutrient analyses and filters were sent to the University of Notre Dame for chlorophyll *a* analyses. Unknown fish identifications were verified in the laboratory and corrected on the datasheets. All 2017 data, except for lab water quality data and macroinvertebrate identification data, have been entered into the on-line database, and were QC'd by a second reader. Macroinvertebrate data identification will begin this month and will likely be completed by early 2018.

Water levels were extremely high this year across all sites, making it difficult to find vegetation zones that could be sampled with our protocols. Many zones were ~1 m deep or deeper and therefore a number of zones were only sampled for macroinvertebrates and not fish. For example, site 792 in Munuscong had 4 zones sampled for macroinvertebrates and none for fish due to depth. Also, we did observe *Phragmites* becoming more dominant in areas such as Sand Island and Munuscong Bay this year, which may be associated with the higher water levels.

As was mentioned in previous reports, NOAA led efforts on a restoration of flow through the Little Rapids in the St. Marys River. Construction was complete in November 2016. Site 814 (Sugar Island 3) was added as a benchmark in 2013 to characterize changes in fish communities, and it was sampled in 2017 to follow up on wetland changes. Continued monitoring of this site before and after restoration will help identify changes to existing wetlands and to their use by fishes and other aquatic organisms at various life stages.

Also, in September 2017, Ashley Moerke presented an overview of the GL Wetland Monitoring program at the Upper Peninsula Environmental Coalition meeting in Sault Sainte Marie. This was a community event that had about 50 people in attendance. In 2016, Ashley gave a similar presentation to the Sault Naturalists, a non-profit group that includes US and Canadian citizens interested in natural science issues in the region.

100% of the 2017 field data has been entered; 100% has been checked by a second person. 2017 macroinvertebrate samples have not yet been identified and 0% have been entered. All lab samples are out for analysis, and therefore 0% of lab data have been entered.

UNIVERSITY OF WISCONSIN GREEN BAY

Bird and Amphibian Crew

We successfully completed the 2017 UW-Green Bay field season for the EPA-funded Great Lakes Coastal Wetland Monitoring Program in early July 2017, yielding bird samples from 34 wetlands and anuran samples from 25 of these. All of the data have been double entered and have been incorporated into the GLCWMP database. Four students were employed as field assistants during April-July.

This year's surveys were unusual because we did not have any students available who were qualified adequately to identify bird vocalizations. Hence, Erin Giese and Dr. Robert Howe led the bird surveys, with assistance from Dr. Amy Wolf. Howe and Giese passed the online birder certification web test to verify their qualifications to conduct surveys.

Water levels were near record highs during the counts, providing an outstanding opportunity to compare results with the low water years from 2011-2014, including the record low levels of early 2013.

Tara Hohman, a new UW-Green Bay graduate student, began her work in September 2017; she hopes to study the effects of water levels on wetland birds and anurans, relating the two data sets if possible.

The GLCWMP continues to play a significant role in our EPA/Wisconsin DNR-funded project to develop a strategy to de-list the Lower Green Bay and Fox River Area of Concern (AOC) with respect to fish and wildlife populations. Both the field data and the environmental indicator framework developed during this project are being incorporated.

In March 2017 UW-Green Bay graduate student and GLCWMP field assistant Willson Gaul completed his Master's thesis entitled "Uncertainty estimates for a quantitative ecological indicator." Willson was accepted in the graduate program at University College in Dublin, Ireland, where he currently is continuing his post-graduate education. A manuscript based on this work is currently in the later stages of preparation.

Preparation of a long-overdue manuscript on bird indicator metrics is near completion, and a draft is expected to be ready for submission by early 2018. Scholarly presentations related to our AOC-GLCWMP assessment tool have been shared at several conferences and workshops. One of our students, Maria Otto, summarized results from our anuran surveys in the bay of Green Bay as part of the WISYS Quick-Pitch Competition at UW-Green Bay during April 2017. She was awarded a cash prize for her runner-up finish and participated at the statewide competition at UW-Platteville during July.

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

Site Selection

The College at Brockport worked with Environment Canada and Bird Studies Canada in late winter to redistribute site assignments to match crew capacities relative to the spatial distribution of sites. Eight Environment Canada sites from the Canadian shore of Lake Ontario were reassigned to Brockport for fish, aquatic macroinvertebrates, water quality, and vegetation sampling, and two additional Canadian sites were also reassigned to Brockport for bird and amphibian sampling. Three wetlands, all located in the Rochester Embayment Area of Concern, received benchmark tags for Brockport to collect data for ongoing restoration projects. These included Long Pond (29), Buck Pond (51), and Salmon Creek (28). In all, The College at Brockport was assigned 24 sites to perform fish, aquatic macroinvertebrate, water quality, and vegetation sampling, and 25 to perform bird and amphibian sampling.

Training

Approximately 40% of Brockport's 2017 crew members were returning members from the 2016 field season, with these returning members' areas of expertise spread out across the various sampling groups. The remaining 60% of the crew received new crew-member training by Brad Mudrzynski, Dr. Douglas A. Wilcox, and Dr. Chris Norment, and all passed training requirements. Additionally, all crew-members passed mid-season QA checks performed by Brad Mudrzynski and Dr. Chris Norment.

Sampling

The College at Brockport bird and amphibian sampling crew successfully sampled 24 of the 25 sites assigned to them between 20 March and 15 July 2017. Sampling efforts were hindered by lake levels about a meter above average. The one unsampled site, Deaborough Park Area Wetland (72), was a site reject due to lack of connectivity with the lake. The bird and amphibian crew was also prohibited from completing the second round of bird counts and the third round of frog counts at Big Sandy Bay (5091) by site management, as the high lake waters were deemed unsafe. They also had to do their point counts for round two of birds and round three of amphibians at different locations at Thompson Bay (1941), as park rangers had closed off the area where they counted from earlier in the summer.

The summer fish, aquatic macroinvertebrate, water quality, and vegetation crews were assigned 24 sites. Due to the high waters and access issues, not all sites were sampled by each crew. In total, the fish crew sampled 11 of 24 sites, the invertebrate and water quality crew sampled 17 of 24 sites, and the plant crew sampled 20 of 24 sites. Big Sandy Bay (5091) was not sampled due to lack of boating access, Airport Creek Marsh (5007) was not sampled due to safety concerns, and two sites, Deaborough Park (72) and Bath Point (5049) did not have connectivity to the lake. In addition, sites where fish, invertebrates, and water quality were not sampled included Long Pond (29), Irondequoit Bay (7053), and Sawguin Creek Marsh 2 (5870). The water was too high to fit boats under bridges at Long Pond and Irondequoit Bay, and there was no boat access at Sawguin Creek. Due to lack of access for the larger boat, the fish crew was unable to sample Mud Bay Marsh 1(197), and 2 (199), Golden Hill (8), Chaumont River Mouth Wetland (167), Little Fox Creek (188), and Hay Bay Marsh 1 (5400).

Laboratory Work

Laboratory analyses of water samples at The College at Brockport are finished, while aquatic macroinvertebrate identification has just begun and is approximately 17% complete and will be complete by the end of December.

Data Entry and QC

Bird and amphibian data are 100% entered, with approximately 80% of bird and amphibian data having received all quality control checks. Vegetation data entries are greater than 95% complete, with GPS and transect data as the remaining data to be entered. Data entry has just started for fish, field-level water quality, and field-level aquatic macroinvertebrate data, and all quality control checks for field-level data should be finished by early winter. Data entry for aquatic macroinvertebrate laboratory identifications has not started because identification has just begun.

Working with Local Groups

The College at Brockport continued to work closely with restoration partners to collect more pre- and post-restoration data at a few wetlands near Rochester, NY. Long Pond, Salmon Creek, and Buck Pond received a benchmark tag to collect data for the US Fish and Wildlife Service restoration project, with 2017 data serving as post-restoration data.

Buck Pond was also surveyed as a Benchmark in 2017 to collect more data for the Ducks Unlimited restoration project that was performed in 2014. All data collected will be considered post-restoration data, with a focus on sharing bird, amphibian, vegetation, and fish data, as those are the data Ducks Unlimited is most interested in.

Finally, The College at Brockport continued to communicate invasive species presence to local authorities during the 2017 Coastal Wetland Monitoring Program. The main invasive species reported during the summer continued to be water chestnut (*Trapa natans*). The College at Brockport notified the Finger Lakes office of the New York State Partnership for Invasive Species Management (FL-PRISM) for infestations they found in Braddock Bay and Long Pond (29). The New York Department of Environmental Conservation, the agency that owns these wetlands, worked with FL-PRISM during the summer months to find and eradicate most the infestations that were reported field crews.

High Water Levels

The high water on Lakes Ontario and Erie created some challenges with sampling. There were several instances where our boats could not pass under bridges to access wetlands, and others where boat launches were entirely under water. There were two instances where the fish crew did not meet the QA/QC check of 10 total vertebrates in three nets that required a resetting of nets. This is the first time this has happened during the seven years of the project for the crew at Brockport. Our bird and amphibian crew found that many of the points they chose in spring were inundated by about one meter of water when they returned on subsequent visits. In one instance, the site was deemed by a caretaker to be unsafe to access, and in another they were asked to move their point to dry land.

This was an exceptional year for focal bird species, as Virginia Rail, including fledglings, were documented at four sites, Common Gallinule at three sites, and Least Bittern at five sites. During an amphibian count at Big Sandy Bay, seven American Bitterns were recorded. Lastly, a Pied-billed Grebe, which is a rare bird in this area, was recorded during an amphibian count at Little Sandy Creek.

Canadian and US Western Lake Erie Regional Team: Jan Ciborowski, Joseph Gathman (fish, macroinvertebrates and water quality), Carla Huebert (vegetation), Doug Tozer (birds and amphibians), and Jennifer Jung and Greg Grabas (north shore of Lake Ontario – water quality, fish, macroinvertebrates, vegetation)

Field Training

Birds and Amphibians

Training for birds and amphibians was delivered by PI Doug Tozer on May 17, 2017 at Bird Studies Canada National Headquarters in Port Rowan, Ontario. Three crew members were in attendance. Several returning crew members did not attend the training session in Port Rowan, but did receive a refresher on field protocols from PI Doug Tozer via telephone and email prior to the start of field surveys. Field personnel were instructed in the project's objectives and methodology, and site selection procedures and station placement guidelines within selected wetlands. The amphibian and bird survey field protocols were covered in detail. Field personnel were also instructed in methods of reporting, safety, data entry, and assessed for their ability to use GPS instruments with adequate precision and accuracy as per the quality assurance project plan. Comprehension of the topics was evaluated with a written and practical test. All people collecting data also successfully completed the online amphibian and bird identification tests. A mid-field-season check was made by Doug Tozer. No problems were identified.

Fish, Macroinvertebrates, and Water Quality

Canadian Wildlife Service (CWS) field crew members who worked with fishes, macro-invertebrates, and water quality sampling were trained by Jennifer Jung and Ian Smith in the Toronto Region during June and August field visits**.** A number of crew members returned from previous years and all members participated in training on project protocols. The sampling protocol, technical equipment use, occupational health and safety, and field-based decision-making were covered in detail over multiple days. Crew members were assessed in the field and lab for proper sample collection, data recording, GPS use, field lab water processing, equipment calibration, and lab sample preparation and storage. An experienced staff member was paired with new personnel to reinforce project protocols and ensure high data quality. In June, Jennifer Jung gave refresher training to the water quality and invertebrate sampling crew. Ian Smith trained the fish sampling crew. Joe Fiorino attended the Royal Ontario Museum's course in fish identification. A mid field-season check was conducted in August. No problems were identified.

Continuing University of Windsor field crew members who worked with fishes, macro-invertebrates, and water quality sampling had worked on the project in 2015, and so only a review and refresher of protocols was needed for those individuals. They were also engaged in training new field crew members. The training and review included instruction in GPS use, assessment of whether sites met project criteria (open water connection to lake, presence of a wetland, safe access for crew), identification of vegetation zones to be sampled, water quality sample collection, preprocessing and shipping to water quality labs, calibrating and reading field instruments and meters, setting, removing, cleaning and transporting fyke nets, and protocols for collecting and preserving macroinvertebrates. Crews received additional training and testing in field data and lab entry. All field personnel were given refreshers in basic fish identification training. All field team members were given field and lab safety training, and were required to re-read the Standard Operating Procedures for the project. New members were trained in all project procedures, and were certified by crew leader Joseph Gathman in late June. Mid-season checks were performed in early August.

Vegetation

Vegetation surveys were conducted by expert botanist Carla Huebert (returning each year since 2013). She received the same general instructions and project orientation as did the other groups. In addition, she reviewed the specific vegetation sampling methodology and data recording methods outlined in the QAPP and modified at the January 2017 Principal Investigators meeting. For the CWS crew, Greg Grabas and Jennifer Jung co-led the vegetation sampling and identification. Various summer students and Canadian Wildlife Service personnel assisted in data collection and acted as data recorders.

Water Quality Samples

Water quality sampling followed the protocols dictated by the QAPP as developed by the GLWMP water quality team (PI Dr. Rich Axler). Metered measurements were made and water samples were collected at the time that fyke nets were placed in the water. Water samples were stored refrigerated on ice in darkness until the evening, at which time they were processed and prepared for shipment to the analytical laboratory. With the exception of Chlorophyll *a* samples, which were shipped and analyzed by colleagues at the University of Notre Dame University, all laboratory analysis was conducted by Environment Canada's National Laboratory for Environmental Testing (NLET) in Burlington, ON. The lab received samples by overnight express courier to ensure that they complied with QAPP specified holding times. All analyses have been completed. Field-based measurements have been entered into the water quality database. Analytical laboratory data have been entered into the database, and are receiving final QA review.

Site selection and field sampling, and results

Bird and amphibian field crews evaluated 60 sites that had been selected and ordered for potential sampling in 2017 (26 on Lake Ontario, 24 on Lake Huron, and 10 on Lake Erie). Of these, 12 were not surveyed because boat access was not possible. Forty-eight sites were visited (each on 5 occasions) and sampled for amphibians and birds.

Fish, Macroinvertebrates, Water Quality, and Wetland Vegetation
The CWS crew visited and evaluated 10 locations along the north shore of Lake Ontario. The University of Windsor crew was initially assigned 36 sites on lakes Erie and Huron or the connecting channels. Three of these sites were sampled for vegetation only on behalf of the Uzarski team. Of the remaining 33 sites, five were rejected without being visited. (One site was on aboriginal land and we were unsuccessful in making contact to request permission for access. One site was too far from a boat ramp to be safely accessible; one site was a shrub swamp; one site was both unconnected to its lake and did not meet the minimum size criterion; and one site was generally unsuitable). Thus, 28 sites were visited by fish/invertebrate crews, and two of these were not sampled. (One lacked vegetation zones that met project criteria for sampling fish or invertebrates and the other had become isolated from the lake due to placement of an earthen barrier). Therefore, the combined efforts of CWS and Windsor crews resulted in a total of 10 sites sampled Lake Ontario, 10 on Lake Erie (2 of which were in Ohio and 3 in Michigan), 2 in Lake St. Clair, and 19 in Lake Huron (including the North Channel, St. Marys River and Manitoulin Island).

Vegetation was surveyed at 40 sites, three of which were sampled for the Central Michigan University crew (for vegetation only). In total, 26 sites were suitable for water quality and macroinvertebrate sampling, and 24 sites were sampled for fishes. The full suite of water quality, fishes, macroinvertebrates and wetland vegetation was assessed at 33 sites by our group (23 by Windsor and 10 by CWS on Lake Ontario).

Benchmark sites
Three benchmark sites were identified for sampling in 2017 (Crane Creek, in the Ottawa National Wildlife Refuge, OH; Collingwood, in Lake Huron; and Stobie Creek, in the North Channel). The Crane Creek site continues to be a study area of interest to the USGS, who wished to see how the findings of their GLRI-funded work compared with the results of surveys using the standardized Coastal Wetland Monitoring methodology (K. Kowalski, USGS, Ann Arbor, MI, *pers. comm.*). This site had been sampled annually beginning in 2012. We expect to continue our collaboration with the USGS team to compare our among-year estimates of variation with their repeated-sampling-within-year design. This will provide important information on the degree to which a single, synoptic visit represents the community as assessed by repeated sampling over the course of a field season. The Stobie Creek site has been targeted for some restoration work, so the Kensington Conservancy asked us to collect baseline data there.

Data Entry and Quality Assurance

Most bird and amphibian data have been entered and quality assured; some data entry remains and will be completed later this autumn. All fish, vegetation, and field-collected water quality data have been compiled, entered into the database, and quality assured. Most macroinvertebrate samples collected by the Windsor team have been examined, identified to the family level, entered into the database, and the identifications quality checked according to QAPP protocols. Identification of invertebrate samples from the Lake Ontario sites sampled by CWS will begin shortly. We have received, entered and Quality Assured laboratory analyses of Water quality data from all but 2 sites.

Significant Observations

Birds and Amphibians

Of note were 72 point occurrences of 8 Ontario bird species at risk, based on information currently in the database; totals for some of the species will increase after remaining bird and amphibian data entry is completed later this autumn. Despite incomplete data, occurrences of threatened Least Bitterns in 2017 already exceed the total for this species in 2016, perhaps due to rising water levels and associated increasing habitat quality in coastal marshes, a pattern we also observed in other species of marsh birds that are not at risk.

		No. Occurrences	
Species	**ON-ESA/SARA Status***	**2016**	**2017****
Acadian Flycatcher	endangered	1	0
American White Pelican	threatened	1	0
Bald Eagle	special concern	10	1
Bank Swallow	threatened	19	9
Barn Swallow	threatened	76	38
Black Tern	special concern	8	0
Bobolink	threatened	0	0
Chimney Swift	threatened	18	3
Common Nighthawk	threatened	2	3
Eastern Meadowlark	threatened	1	1
Least Bittern	threatened	11	16
Red-headed Woodpecker	threatened	1	1
Total		**148**	**72**

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

** Totals for 2017 are preliminary due to incomplete data entry; occurrences for some species will increase once data entry is complete.

Also of note were 2 occurrences of Chorus Frog, which is listed as threatened in Canada (vs. 19 observations in 2016). As with the bird occurrences reported above, this total is expected to increase once amphibian data entry is complete.

Fishes and Invertebrates

Non-native Round Gobies were found by the CWS team at 4 Lake Ontario wetlands, 3 of which were situated in the Bay of Quinte and one along the north shore of Lake Ontario (Grafton Swamp). In addition Round Gobies were captured at 7 Lake Huron sites. Tubenose Gobies were collected at sites on Roberts and Quarry islands in Severn Sound and at Lake St. Clair marshes. The Lake Huron records confirm that Tubenose Gobies (first observed in Severn Sound last year) are becoming well established in this location.

Relatively few other species of note were observed during the 2017 field season. A single Warmouth was captured at Hillman Marsh of Lake Erie.

Water levels in lakes Erie and Huron remained high in 2017 although they were not as high as had been observed in 2016. The trend is resulting in a gradual shift in the relative distribution of aquatic plants. In particular, some sites are exhibiting a reduction in the extent of monospecific stands, and a greater prevalence of species interspersion. In some cases, this has made it difficult to find locations for setting fyke nets that comply with monodominant morphotyphic zone SOPs. As was observed last year, sampling in some areas was hampered by the presence of shrubs that have been inundated by rising water levels. In other areas, bulrush stands are situated in water that is too deep.

Similarly, Lake Ontario water levels were well above the long-term average. The CWS crew has traditionally fished in the submergent or emergent zones. For 3 of 10 sites these areas were too deep (>1 m) to set the fyke nets. In general, fish abundances were lower than normal at sites sampled. Sampling was not conducted in the flooded meadow due largely to logistical issues with access.

Sampling for fishes in Canada requires 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). All permits had been approved both by CWS and by the University of Windsor at the start of the sampling season. Draft reports and sampling records have been sent to regional administrators as per the license requirements. Records of fishes caught will also be sent to local conservation groups in Ontario where appropriate.

Reptiles

The Canadian Wildlife Service is responsible for developing recovery strategies and management plans for turtle species listed as at risk in Canada. As required under the Species at Risk Act (SARA), critical habitat is a required component of the Recovery Strategy for four at risk turtles in Ontario: Blanding's Turtle (*Emydoidea blandingii*) Great Lakes/St. Lawrence population, Eastern Musk Turtle (*Sternotherus odoratus*), Spotted Turtle (*Clemmys guttata*), and Spiny Softshell Turtle (*Apalone spinifera*). Critical habitat is the habitat necessary for the survival and recovery of a species, and may be based on the suitable habitat where turtles have been observed. Examples of suitable habitat for these turtle species are wetlands and watercourses; such as marshes, rivers, and some lakes. Incidental observations from the Great Lakes coastal wetland monitoring project of the Great Lakes Restoration Initiative (GLRI), as well as other sources of turtle observations were used to identify suitable habitat locations in Ontario for proposal as candidate critical habitat for the four species specific recovery strategies. The data provided from GLRI were invaluable in providing evidence of multiple turtle sightings, thus identifying additional or confirming critical habitat sites.

Three Eastern Snapping Turtles (*Chelydra serpentina*) were recorded at 2 of 10 wetlands. All of the Snapping Turtles were caught in SAV zones. This will help identify additional coastal wetlands of conservation significance for this species of special concern. No Stinkpots (Common Musk Turtles) were recorded during this year's sampling.

Other notes:
Five of 10 wetlands have previously been sampled (2012-2013).
The only site where a Stinkpot was observed during a previous visit was Pine Point (5735) in 2013.None were observed this year.

<u>Vegetation</u>
Recent sampling seasons have represented years in which lake levels have risen significantly after a prolonged period of low water. This has produced some interesting new data patterns in that to some extent the water levels have changed more rapidly than has the distribution of the aquatic plants normally characteristic of particular depth zones. Furthermore, the sampling designs of macrophytes, invertebrates and fishes are all tied to the locations of zones and classes of emergent vegetation. As in past years, delineating between vegetation zones was sometimes a challenge, as the species that normally are found in monoculture were often found mixed with other species. Also, because many of the meadows were flooded, plants that one usually finds growing in the emergent and submergent zones were present deep in the meadow zone, and sedges and other meadow species could be found growing far out into what should be the emergent zone. Consequently, we anticipated that the data summaries for 2016 would show greater species richness and diversity within submergent, emergent and wet meadow zones that was observed in the initial years of the CWM program.

With sustained high lake levels again in 2017, we observed further thinning of some types of emergent vegetation. The gaps between meadow species and more flood-tolerant emergent species (cattails, bulrushes) were beginning to fill in with those other types of vegetation.

However, high water continued to preclude fish sampling in many stands of bulrush, and even cattail in many locations. However, at other sites, we noted that cattail stands that had previously been too dense for us to penetrate now had large gaps, which allowed us to get far enough into the zone to find water that was shallow enough to set fish nets.

Certainly, in lower water level years it was much easier to distinguish the boundaries between vegetation zones. This year, we undertook additional sampling along transects of increasing depth to determine whether the invertebrate and fish assemblages more closely reflect former associations with plant zones or with the current water depths at which the plant zones were previously found. This project is forming the basis of Danielle Gunsch's M.Sc. thesis.

Water levels in Lake Ontario were also well above average in 2017. Delineation of the vegetation zones was a challenge. In particular, flooding of the meadow zone made classification difficult due to the lack of meadow plant species present. Areas that would have been classified as meadow in the past were classified as meadow if there were living meadow plant present, merged with the emergent zone if there was sufficient emergent species that were similar in composition to the traditional emergent zone or not surveyed if there was a lack of meadow plants and a dominance of submergent plants. As a result of the flooding there was greater mixing of plant types, with submergent plants frequently recorded in the emergent and meadow zones. In several cases the cattails on the lower end of transects showed signs (e.g., premature yellowing) of stress from the high water levels.

With new knowledge of the presence of Starry Stonewort (*Nitellopsis obtusa*) in the Lower Great Lakes, surveyors made extra effort to look for and positively identify this non-native macroalga during wetland surveys. In total, 4 of 11 Lake Ontario wetlands sampled contained *Nitellopsis,* which was identified during vegetation sampling. All wetlands with positive records were located in eastern Lake Ontario, which has been shown to have both a greater areal extent of wetland habitat and higher IBI scores than western portions of Lake Ontario. Canadian Wildlife Service has identified *Nitellopsis* in Canadian portions of Lake St. Clair and the Detroit River.

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

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

We have also continued to monitor expansion of the distribution of invasive *Phragmites* in wetlands of southeastern Lake Huron. During the period of successive low water years, many wetlands in this area, up to the Bruce Peninsula, were left stranded, or perched, above a rocky shoreline that was exposed by the low water. The bedrock shelves prevented wetland expansion into the lower-elevation rocky substrates. However, *Phragmites* colonized these areas though outgrowth of horizontal rhizomes. This had led to the establishment of *Phragmites* beds at a lower elevation than these wet meadows, and lower even than some of the more hydrophilic marsh plants (e.g., bulrush), now that the water has risen. It would be informative to establish a standard protocol for monitoring these *Phragmites* patches relative to water levels to see how these new monoculture areas develop. This could represent a significant new mode of expansion of this aggressively invasive species. We are considering designating some of these locations as special benchmark sites for a sub-project on *Phragmites* patch development.

In general there is less *Phragmites* present in Lake Ontario than Lake Erie. The regulation of Lake Ontario water levels likely contributes to this observation as regulation result in relatively stable water levels which expose shorelines less frequently than a naturally fluctuating system. *Phragmites* was found by the CWS crew at four Lake Ontario wetlands, one along the north shore of Lake Ontario, and the other three in the Greater Toronto Area. This is consistent with other surveys that have found greater amounts of *Phragmites* in more developed areas.

Another invasive plant that has been observed within most of the Lake Erie and Lake St. Clair wetlands is *Hydrocharis morsus-ranae* (European Frogbit). This small floating plant appears to be most plentiful and potentially problematic within high nutrient sites. Wetlands located in agriculturally-dominated watersheds tend to experience the highest populations and in some locations the biomass was of sufficient density to prevent access by fish and other aquatic wildlife. In many of the wetlands in which this species is present it is not mono-dominant.

Collaborations and Project Leverage Examples

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

Bird Studies Canada in collaboration with all other bird and frog PIs combined CWM bird data with data from another broad-scale marsh bird monitoring program—the Great Lakes Marsh Monitoring Program (GLMMP)—in a peer reviewed paper entitled "*Influence of call broadcast timing within point counts and survey duration on detection probability of marsh breeding birds*". This manuscript, soon to be published in *Avian Conservation and Ecology*, was enhanced substantially by CWM data, resulting in a final combined sample size of 23,973 point counts! The paper makes recommendations to improve efficiency of marsh bird point counts, which will not only improve the marsh bird component of the CWM program, but will contribute greatly to improved wetland conservation wherever standardized marsh breeding bird point counts are conducted throughout North America.

In 2017 we continued efforts to develop and foster good stakeholder relationships and to continue existing collaborations with local groups around the Great Lakes. We engaged in discussion and/or site visits with the following individuals or groups during the 2017 field season:

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

Kurt Kowalski (USGS; work at Crane Creek marsh, Ottawa National Wildlife Reserve) - comparing methods and presumably results of USGS vs. CWM initiatives. We have continued to sample Crane Creek Marsh as a Benchmark site to continue our ongoing collaboration with the USGS lab. We will apply both CWM metrics and GLEI-derived indicators of fish and plant condition to our annual data and will compare these 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.

Kensington Conservancy (Lake Huron's North Channel near Bruce Mines) – we have coordinated with them over the last five years, mainly for information sharing on sites. This year, we designated Stobie Creek as a benchmark site at their request.

Lambton Shores *Phragmites* Community Group (near Kettle Point, ON, southern Lake Huron) – Bird Studies Canada collected marsh bird and frog data before and after *Phragmites* control in one of the marshes targeted by this group. We have provided these data and interpretation of them to help measure success. Bird Studies Canada is also working with this group to monitor other mostly inland marshes of interest through the volunteer-based Great Lakes Marsh Monitoring Program.

ASSESSMENT AND OVERSIGHT

The Quality Assurance Project Plan (QAPP) for this program was originally written, signed by all co-PIs, and approved by US EPA in the spring of 2011, prior to beginning any fieldwork. Throughout the first round of the project (2011-2015) 5 revisions were made to the QAPP. These revisions were necessary to improve methodology, better clarify protocols, and ensure the safety of all personnel. After each revision, all co-PIs and US EPA reviewed and signed the updated document prior to commencing fieldwork. The final QAPP revision for round 1 of the project was signed in March 2015. This 2015 revision (QAPP_r5) served as the basis for the second round of monitoring (2016-2020).

For the second 5-year sampling rotation, no substantial methodological or quality assurance/quality control changes were necessary. The QAPP_r5 document was reviewed by project PIs prior to our February 19, 2016 project meeting. The only changes that were required to QAPP_r5 related to the data management system. Specifically, an update was added noting how the data management system developed by LimnoTech and housed at Central Michigan University will be backed up. Project PIs signed the updated QAPP (QAPP_CWMII_v1) at the February 19, 2016 meeting. This QAPP was reviewed and approved by all project co-PIs at our February 10, 2017 meeting. The QAPP will be updated before the third year of round 2 sampling to clarify some water quality elements and eliminate a few inconsistencies.

Major QA/QC elements that are on-going for this work:

- 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. In conjunction with the 2017 annual program meeting, invertebrate taxonomists from all labs met the day before the meeting to discuss thorny taxonomic identifications and to decide how to incorporate changes in taxonomy based on an update of one of our most important identification manuals.

- Training of all fish, macroinvertebrate, vegetation, bird, amphibian, and water quality field crew members following the QAPP and SOPs. This included passing tests for procedural competence, as well as identification tests for fish, vegetation, birds, and amphibians. Training certification documents were archived with the lead PI and QA managers.

- GPS testing: Every GPS unit used during the 2015 field season was tested for accuracy and its ability to upload data to a computer. Field staff collected a series of points at locations that could be recognized on a Google Earth image (e.g., sidewalk intersections) then uploaded the points to Google Earth and viewed the points for accuracy. Precision was calculated by using the measurement tool in Google Earth. Results of these tests have been archived and referenced to each GPS receiver by serial number.

- Review of sites rejected after initial site visits: In cases where a site was rejected during a site visit, the reason for rejection was documented by the field crew in the site selection database. The project QA officers (Brady and Cooper) then reviewed these records to ensure consistency among crews. Occasionally, field crew leaders contacted Uzarski, Brady, or Cooper by cell phone when deciding whether to reject a site. However, given that most crew leaders have been with the project for over 5 years, they are able to make these decisions more independently than in previous years.

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

- Maintenance, calibration, and documentation for all field meters: All field meters were calibrated and maintained according to manufacturer recommendations. Calibration/maintenance records are being archived at each institution.

- Collection of duplicate field samples: Precision and accuracy of many field-collected variables is being evaluated with duplicate samples. Duplicate water quality samples were collected at approximately every 10th vegetation zone sampled. A summary of these results is included below.

- 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 2011-2016 data and is partially complete for 2017 data. QC should be complete for 2017 data in the spring.

- Linking of GPS points with field database: Inevitably, some errors occur when crew members type in GPS waypoint names and numbers. Even a space or capitalization in the wrong place can break the link between the GPS database file and the field data database. All non-linking points between these two databases were assessed and corrected in 2014. We are currently exploring ways to make this checking and reconciliation more automated.

- Mid-season QC checks: These were completed by PIs for each of the field crews to ensure that there were no sampling issues that developed after training and while crews were sampling on their own.

- Creation/maintenance of specimen reference collections: Reference collections for macroinvertebrates, fish, and plants have either been created or are being maintained and updated by each regional team. Macroinvertebrate reference collections, in particular, were developed or expanded as these samples were processed. Labs that have uncommon invasive specimens (e.g., faucet snail, New Zealand mud snail, etc.), are sharing those specimens with other labs. Vegetation reference collections are often being kept in collaboration with local herbaria.

- 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 will be linked to the primary data that is being generated (see example report below).

Example Water Quality QC Information

Laboratory Quality Assurances:
Water quality analyses from 2017 have been partially completed by the NRRI Central Analytical Laboratory, Central Michigan University's Wetland Ecology Laboratory, Grand Valley State University's Annis Water Resources Institute, Brockport's water quality lab, and Environment Canada's National Laboratory for Environmental Testing. Laboratory results from 2016 have passed (or will pass) the criteria shown below (Table 16).

Table 16. 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 six project years is shown in Table 17. 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 17 below lists average RPD values for each year of the project (2011-2016). 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 17. An assessment of field duplicate sample variability in relative percent difference for water quality parameters. The maximum expected RPD values are based on the MN Pollution Control Agency quality assurance project plan.

Analyte	MDL	Maximum expected RPD	2011	2012	2013	2014	2015	2016
Chl. *a*	< 0.5 µg/L	30	*65.2 (5)	20 (5)	28.4(8)	31.6 (7)	*65.8 (4)	37.0(2)
Phaeophytin	< 0.5 µg/L	30	19.4 (5)	75(5)	29.9(8)	32.7(7)	*51.9(4)	45.6(2)
Total P	< 0.002 mg/L	30	24.8 (5)	18(5)	23.6(8)	15(7)	16.7(4)	17.7 (2)
Sol React P	< 0.002 mg/L	10	13.7 (5)	16(5)	6.3(8)	10.3(7)	8.2(4)	23.2 (2)
Total N	< 0.010 mg/L	30	10.9 (5)	7.1(5)	6.7(8)	30.7(7)	25.2(4)	14.6(2)
NH4-N	< 0.002 mg/L	10	**66.4(5)	11(5)	**47.8(8)	30.7(7)	27.2(4)	37.8 (2)
NO2/NO3-N	< 0.002 mg/L	10	**48.3 (5)	12.3(5)	24.8(8)	12.2(7)	5.2(4)	26.1(2)
True color	< 5 units	10	7.7 (5)	5(5)	2.9(7)	6.2(7)	5.2(4)	10.2(2)
Turbidity	< 0.4 NTU	10	10.4 (4)	3 (5)	5.8(6)	7.0(4)	38(2)	4.3(2)
chloride	< 0.5 mg/L	20	12.3 (5)	2.6(5)	3.1(6)	6.6(7)	2.2(4)	4.4(2)
ANC	< 0.5 mg/L	10	2.9 (4)	--	1.4 (6)	--	--	--

*Many of the chlorophyll field replicates were < 2 µg/L or 4 times the MDL (range 0.3 – 1.8). **The variability between ammonium-N and nitrate/nitrite-N field replicates also exceeded the criteria however many values for each were < 10 X the MDL (i.e. < 0.02 mg/L).

Communication among Personnel

Regional team leaders and co-PIs continue to maintain close communication as the project is in its seventh year (second field season of round 2 sampling). The lead PI, all co-PIs, and many technicians attended an organizational meeting in Bay City, Michigan on February 10th, 2017. During this meeting, the group discussed issues pertaining to manuscript topics and report products. Dr. Kevin O'Donnell (EPA) discussed ongoing and potential future coastal wetland restoration projects and how our group could contribute by monitoring the success of these efforts. Personnel from USGS presented an update on a collaborating project to better understand the functions that wetlands provide to nearshore areas. For example, what fish species spawn in wetlands or use them as nursery areas? How much invertebrate export there is to the surrounding landscape? This spin-off project began fall 2016 with US crews from NRRI, Northland, CMU, and Brockport.

Regional team leaders and co-PIs have held conference calls and e-mail discussions regarding site selection, field work preparation, and taxonomic changes 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 had many returning and experienced personal, which made training and sampling efficient in 2017. 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 seventh season. Because of the potentially dangerous nature of the work, the entire project team is very relieved to have all their crew members kept safe. This is due to the leadership and safety consciousness of PIs, field crew chiefs, and field team leaders. PIs are trying not to be complacent about the lack of injuries and the willingness of their crews 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. From the PI and QA managers' perspectives, the seventh field season was as successful as previous years despite the challenges of very high water levels on the Great Lakes.

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.

LEVERAGED BENEFITS OF PROJECT (2010 – 2017)

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)

Assessing Climate Vulnerability in Apostle Islands Coastal Wetlands: Funded by the National Park Service and GLRI, a team from Northland College sampled fish, macroinvertebrates, vegetation, and hydrologic variables in lagoon wetlands throughout the Apostle Islands National Lakeshore to identify species and communities that may be particularly vulnerable to climate change. This work represents an intensification of sampling effort within a sensitive and relatively pristine area of the Great Lakes. Data from this project will be analyzed in relation to CWMP data to put Apostle Islands wetlands into a broader Great Lakes context.

Functional Indicators of Coastal Wetland Condition: Funded by the USGS through a Cooperative Ecosystem Studies Unit (CESU), this pilot project began in fall 2016 to better determine functional indicators of Great Lakes coastal wetland usage by Great Lakes fish species. Sampling is done during the spring and fall at about 15 US wetlands already being assessed for CWM indicators during the summer. Data collected focus on fish usage of wetlands and the forage base for those fish, evaluated using macroinvertebrate sampling and examination of fish gut contents. Special emphasis is placed on determining usage of wetlands by young or spawning fish.

Conservation Assessment for Amphibians and Birds of the Great Lakes: Several members of the CWM 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 of special concern in North America. CWM PIs will use the extensive data that have been gathered by USEPA, 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. The initial stages in the development of the conservation assessment will be to analyze habitat and landscape characteristics associated with Great Lakes coastal wetlands that are important to wetland-obligate bird species occupying these habitats. By combining breeding bird data from the sources above and incorporating landscape variables, classification trees can be developed to predict presence and relative abundance of these species across the Great Lakes Basin. These methods, outlined in Hannah Panci's thesis; 'Habitat and landscape characteristics that influence Sedge Wren (*Cisthorus platensis*) and Marsh Wren (*C. palustris*) distribution and abundance in Great Lakes Coastal Wetlands'(University of Minnesota Duluth). She compiled data for over 800 wetlands in her analysis, which will provide a basis for analyzing additional wetland-obligate species.

Bird and Amphibian Metrics and Indicator Calculations: 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 QC'd to date (2011-2015) are being used to calculate some of the metrics and indicators for these wetlands.

Influence of broadcast timing and survey duration on marsh breeding bird point count results: Several members of the project team, with D. Tozer as lead, examined the importance of survey duration and timing of broadcast playbacks on occurrence and counts of wetland breeding birds. The results of this analysis suggest that 10-min point counts are superior to 15-min counts which have important implications for future monitoring and cost-effectiveness.

These findings have been submitted for publication to the journal of Avian Conservation and Ecology in October 2016.

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.

Using Monitoring Results to Improve Management of Michigan's State-Owned Costal Wetlands: One year project, 2016-2017, awarded to Central Michigan University by the Michigan Department of Environmental Quality. The project will focus on the prioritization of high-quality and important state-owned coastal wetlands that have been monitored as part of the Great Lakes CWM program, and development of site-specific management plans for these wetlands which address diverse management goals and objectives with a broad focus including biodiversity, ecological services, habitat for fish and wildlife, climate change adaptation, and rare species.

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 project, funded by the Upper Midwest and Great Lakes Landscape Conservation Cooperative, has developed a DSS for wetlands from Saginaw Bay to Western Lake Erie and is now expanding into other areas of the Great Lakes.

A Decision Support System for Restoration and Protection of Michigan's Coastal Wetlands: This 1.5 year project funded by the Michigan Department of Environmental Quality and Office of the Great Lakes to Central Michigan University expands upon the project funded by the Upper Midwest and Great Lakes Landscape Conservation Cooperatives by including all sites sampled as part of the CWM throughout the Great Lakes basin.

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: CWM project PIs have 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 biotic 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. This discovery received media attention from Illinois-Indiana Sea Grant College Program.

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 we capture.

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 mapped 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 provided her with vegetation data and sampling locations each year to assist with this effort. Dr. Bourgeau-Chavez was also 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 2014-2017, 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.

Targeting Invasive Plant Species in Wisconsin Coastal Wetlands: In collaboration with WI Department of Natural Resources and Lake Superior Research Institute, vegetation PIs have summarized patterns of invasive plant occurrence in Wisconsin coastal wetlands. These summaries are being used to develop a more comprehensive invasive plant monitoring strategy throughout the Wisconsin basin.

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, the Great Lakes National Park Service, the Nature Conservancy (sites across lakes Michigan and Huron for both groups), as well as state natural resource departments. 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; a New York state project to increase nesting habitat for state-endangered black tern; and projects in Wisconsin to restore degraded coastal wetlands on the Lake Superior shore. 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, wetlands along Wisconsin's Lake Superior shoreline, 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 Creek 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)
- Conservation of Common Terns in the Great Lakes Region (University of Minnesota; with additional funding from USFWS, MNDNR, and multiple smaller internal and external grants).

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 loads in freshwater turtle species inhabiting coastal wetlands of Lake Michigan (University of Notre Dame; additional funding by the UND College of Science, and ECI – Environmental Change Institute). Online coverage found here, TV and radio here.
- Nitrogen-limitation in Lake Superior coastal wetlands (Northland College; additional funding from the Wisconsin DNR and Northland College).
- Patterns in chlorophyll-*a* concentrations in Great Lakes coastal wetlands (Northland College; additional funding provided by the college).
- *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)
- Water depth optima and tolerances for St. Louis River estuary wetland plants (University of Wisconsin-Superior, with additional funding from WI Sea Grant)
- Mapping Wetland Areal Change in the St. Louis River Estuary Using GIS (University of Wisconsin-Superior, with additional funding from WI Sea Grant)
- An analysis of Microcystin concentrations in Great Lakes coastal wetlands (Central Michigan University; additional funding by CMU College of Science and Engineering).

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)
- Modeling species-specific habitat associations of Great Lakes coastal wetland birds (University of Minnesota)
- The effect of urbanization on the stopover ecology of Neotropical migrant songbirds on the western shore of Lake Michigan (University of Minnesota Duluth).
- Nutrient limitation in Great Lakes coastal wetlands: gradients and their influence (Central Michigan University; with additional funding from the CMU College of Science and Engineering)
- Invasive *Phragmites australis* management (Central Michigan University; with additional funding from the CMU College of Science and Technology)
- The relationship between vegetation and ice formation in Great Lakes coastal wetlands (Central Michigan University; with additional funding from CMU College of Science and Engineering)

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 are cumulative):

- Principal Investigators (partial support): 14
- Post-doctoral researchers (partial support): 2 (0.25 – 0.5 FTE)
- Total graduate students supported on project (summer and/or part-time): 40
- Paid undergraduate internship (summer): 1
- Unpaid undergraduate internship (summer): 1
- Undergraduate students (summer and/or part-time): 53
- Technicians (summer and/or partial support): 25 (~12 FTE)
- Volunteers: 25

Total jobs at least partially supported: 123 (plus 25 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, S. and D.G. Uzarski**.** 2016. The Great Lakes coastal wetland monitoring program. 2016 Wetlands Science Summit, Richfield, OH. September, Oral Presentation.

Bozimowski, A.A., B.A. Murry, and D.G. Uzarski. 2012 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. 2015. 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.

Cooper, M., Redder, T., Brady, V. and D. Uzarski. 2016. Developing a decision support tool to guide restoration and protection of Great Lakes coastal wetlands. Annual Meeting of the Wisconsin Wetlands Association, Stevens Point, WI. February. Presentation.

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

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.

Dahlberg, N., N.P. Danz, and S. Schooler. 2017. 2012 Flood Impacts on St. Louis River Plant Communities. Poster presentation at 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.

Danz, N.P. 2017. Connections Between Human Stress, Wetland Setting, and Vegetation in the St. Louis River Estuary. Oral presentation at the Wetland Science Conference, Stevens Point, WI.

Danz, N.P. 2017. 10 Things We Learned from Your Vegetation Data. Oral presentation at the St. Louis River Summit, Superior, WI.

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.

Fraley, E.F. and D.G. Uzarski 2017. The relationship between vegetation and ice formation in Great Lakes coastal wetlands. 60th Annual Meeting of the International Association of Great Lakes Research. Detroit, MI. Poster.

Fraley, E.F. and D.G. Uzarski. 2016. The Impacts of Ice on Plant Communities in Great Lakes Coastal Wetlands. 7th Annual Meeting of the Michigan Consortium of Botanists, Grand Rapids, MI. October. Poster.

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/

Gnass Giese, E.E. 2013. Monitoring forest condition using breeding birds in the western Great Lakes region, USA. Editors: N. Miller, R. Howe, C. Hall, and D. Ewert. Internal Report. Madison, WI and Lansing, MI: The Nature Conservancy. 44 pp.

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.

Houghton, C.J., C.C. Moratz, P.S. Forsythe, G.A. Lamberti, D.G. Uzarski, and M.B. Berg. 2016. Relative use of wetland and nearshore habitats by sportfishes of Green Bay. 59th International Conference on Great Lakes Research, Guelph, Ontario Canada. May. Oral Presentation.

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.

Howe, R.W., N.G. Walton, E.G. Giese, G.J. Niemi, and A.M. Bracey. 2013. Avian responses to landscape stressors in Great Lakes coastal wetlands. Society of Wetland Scientists, Duluth, Minnesota. June 2-6, 2013. Poster Presentation.

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

Howe, R.W., A.T. Wolf, J. Noordyk, and J. Stoll. 2017. Benefits and outcomes of Green Bay restoration: ecosystem and economic perspectives. Presented at the Summit on the Ecological and Socio-Economic Tradeoffs of Restoration in the Green Bay, Lake Michigan, Ecosystem (July 18-20, 2017).

Howe, R.W., A.T. Wolf, and E.E. Giese. 2016. Proposed AOC de-listing process. Presentation to Lower Green Bay and Fox River AOC stakeholders. 16 December 2016.

Howe, R.W., A.T. Wolf, and E.E. Giese. 2017. Lower Green Bay & Fox River Area of Concern: A Plan for Delisting Fish and Wildlife Habitat & Populations Beneficial Use Impairments. A paper presented to AOC Technical Advisory Group. 3 August 2017.

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.

Kneisel, A.N., M.J. Cooper, and D.G. Uzarski. 2016. The impact of *Phragmites australis* invasion on macroinvertebrate communities in the coastal wetlands of Thunder Bay, MI. Institute for Great Lakes Research, 4th Annual Student Research Symposium, Central Michigan University, Mt. Pleasant, MI. February. Oral Presentation.

Kneisel, A.N., M.J. Cooper, and D.G. Uzarski. 2016. Impact of *Phragmites* invasion on macroinvertebrate communities in wetlands of Thunder Bay, MI. 59th International Conference on Great Lakes Research, Guelph, Ontario Canada. May. Oral Presentation.

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.

Kosiara, J.K., J.J. Student, and D.G. Uzarski. 2017. Exploring coastal habitat-use patterns of Great Lakes yellow perch with otolith microchemistry. 60th International Conference on Great Lakes Research, Detroit, MI. May. Presentation.

Kosiara, J.M., J. Student and D.G. Uzarski. 2016. Assessment of yellow perch movement between coastal wetland and nearshore waters of the Great Lakes. 59th International Conference on Great Lakes Research, Guelph, Ontario Canada. May. Oral 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. The Global Freshwater Crisis. Newman University and Notre Dame Alumni Club of Wichita. September 28, 2016.

Lamberti, G.A. The Global Freshwater Crisis. Air and Wastewater Management Association and Notre Dame Alumni Club of Northeastern New York. December 2, 2016.

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.

Lamberti, G.A., M.A. Brueseke, W.M. Conard, K.E. O'Reilly, D.G. Uzarski, V.J. Brady, M.J. Cooper, T.M. Redder, L.B. Johnson, J.H. Ciborowski, G.P. Grabas, D.A. Wilcox, R.W. Howe, D.C. Tozer, and T.K. O'Donnell. Great Lakes Coastal Wetland Monitoring Program: Vital resources for scientists, agencies and the public. Society for Freshwater Science Annual Metting. Raleigh, NC. June4-9, 2017. Poster.

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.

MacDonald, J.L., L.S. Schoen, J.J. Student, and D.G. Uzarski. 2016. Variation in yellow perch (*Perca flavescens*) growth rate in the Great Lakes. 59th International Conference on Great Lakes Research, Guelph, Ontario Canada. May. Oral Presentation.

McReynolds, A.T., K.E. O'Reilly, and G.A. Lamberti. 2016. Food web structure of a recently restored Indiana wetland. University of Notre Dame College of Science Joint Annual Meeting, Notre Dame, IN.

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'Donnell, T.K., Winter, C., Uzarski, D.G., Brady, V.J., and Cooper, M.J. 2017. Great Lakes coastal wetland monitoring: moving from assessment to action. Ecological Society of America Annual Conference. Portland, OR. August 6-11. Presentation.

O'Donnell, T.K., D.G. Uzarski, V.J. Brady, and M.J. Cooper. 2016. Great Lakes Coastal Wetland Monitoring: Moving from Assessment to Action. 10th National Monitoring Conference; Working Together for Clean Water, Tampa, Florida. May. Oral Presentation.

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.

O'Reilly, K.E., A. McReynolds, C. Stricker, and G.A. Lamberti. 2016. Quantifying Lake Michigan coastal wetland-nearshore linkages for sustaining sport fishes. Society for Freshwater Science, Sacramento, CA.

O'Reilly, K.E., A. McReynolds, C. Stricker, and G.A. Lamberti. 2016. Quantifying Lake Michigan coastal wetland-nearshore linkages for sustaining sport fishes. International Association for Great Lakes Research, Guelph, ON.

Otto, M., J. Marty, E.G. Gnass Giese, R. Howe, and A. Wolf. Anuran habitat use in the Lower Green Bay and Fox River Area of Concern (Wisconsin). University of Wisconsin-Green Bay Academic Excellence Symposium, Green Bay, Wisconsin. April 6, 2017. Poster Presentation.

Otto, M., J. Marty, E.G. Gnass Giese, R. Howe, and A. Wolf. Anuran habitat use in the Lower Green Bay and Fox River Area of Concern (Wisconsin). Green Bay Conservation Partners Spring Roundtable Meeting, Green Bay, Wisconsin. April 25, 2017. Poster Presentation.

Reisinger, L. S., Pangle, K. L., Cooper, M. J., Learman, D. R., Uzarski, D. G., Woolnough, D. A., Bugaj, M. R., Burck, E. K., Dollard, R. E., Goetz, A., Goss, M., Gu, S., Karl, K., Rose, V. A., Scheunemann, A. E., Webster, R., Weldon, C. R., and J., Yan. 2017. The influence of water currents on community and ecosystem dynamics in coastal Lake Michigan. 60th International Conference on Great Lakes Research, Detroit, MI. May. Presentation.

Reisinger, A. J., and D. G., Uzarski**.** 2017. Natural and anthropogenic disturbances affect water quality of Great Lakes coastal wetlands. 60th International Conference on Great Lakes Research, Detroit, MI. May. Presentation.

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.

Sierszen, M., Schoen, L., Hoffman, J., Kosiara, J., and D. Uzarski. 2017. Support of coastal fishes by nearshore and coastal wetland habitats. 60th International Conference on Great Lakes Research, Detroit, MI. May. Presentation.

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.

Thoennes, J., and N.P. Danz. 2017. Mapping Wetland Areal Change in the St. Louis River Estuary Using GIS. Poster presentation at the St. Louis River Summit, Superior, WI.

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.

Uzarski, D.G., N. Schock, T.M. Gehring, and B.A. Wheelock. 2016. Faucet snail (*Bithynia tentaculata*) occurrence across the Great lakes basin in coastal wetlands. 59th International Conference on Great Lakes Research, Guelph, Ontario Canada. May. Oral Presentation.

Uzarski, D.G., V.J. Brady, and M.J. Cooper. 2017. The Great Lakes Coastal Wetland Monitoring Program: Seven Years of Implementation. 60th International Conference on Great Lakes Research, Detroit, MI. May. Presentation.

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.

Wheelock, B.A., T.M. Gehring, D.G. Uzarski, G.J. Niemi, D.C. Tozer, R.W. Howe, and C.J. Norment. 2016. Factors affecting current distribution of Anurans in Great Lakes coastal wetlands. 59th International Conference on Great Lakes Research, Guelph, Ontario Canada. May. Oral Presentation.

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 WildlifecManagement Area of Lake Ontario. NY Waterfowl and Wetland Collaborative Network, Oswego, NY. (INVITED)

Wood, N.J., T.M. Gehring, and D.G. Uzarski. 2016. The invasive mute swan impacts on submerged aquatic vegetation in Michigan's coastal wetlands. 59th International Conference on Great Lakes Research, Guelph, Ontario Canada. May. Oral Presentation.

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*.

Danz, N.P., N. Dahlberg, and S. Schooler. 2017. The St. Louis River Estuary vegetation database. Lake Superior Research Institute Technical Report 2017-1, University of Wisconsin-Superior, Superior, WI. 8 pages.

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

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

Langer, T. A., B. A. Murry, K.L. Pangle, and D. G. Uzarski. 2016. Species turnover drives b-diversity patterns across multiple spatial and temporal scales in Great Lakes Coastal Wetland Communities. Hydrobiologia, DOI 10.1007/s10750-016-2762-2.

Schoen, D. G. Uzarski. 2016. Reconstructing fish movements between coastal wetlands and nearshore habitats of the Great Lakes. Limnology and Oceanography, LO-15-0273.R1.

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

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

Uzarski, D.G., V.J. Brady, M.J. Cooper, D.A. Wilcox, D.A. Albert, R. Axler, P. Bostwick, T.N. Brown, J.J.H. Ciborowski, N.P. Danz, J. Gathman, T. Gehring, G. Grabas, A. Garwood, R. Howe, L.B. Johnson, G.A. Lamberti, A. Moerke, B. Murry, G. Niemi, C.J. Norment, C.R. Ruetz III, A.D. Steinman, D. Tozer, R. Wheeler*, T.K. O'Donnell, and J.P. Schneider. 2017. Standardized measures of coastal wetland condition: implementation at the Laurentian Great Lakes basin-wide scale. Wetlands, DOI:10.1007/s13157-016-0835-7.

REFERENCES

Bailey, R. G.; Cushwa, C T. 1981. Ecoregions of North America (map). (FWS/OBS-81/29.) Washington, DC: U.S. Fish and Wildlife Service. 1:12,000,000.

CEC, 1997, Ecoregions of North America, Commission for Environmental Cooperation Working Group (CEC) http://www.eoearth.org/article/Ecoregions_of_North_America_%28CEC%29

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

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

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

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

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

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

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

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

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

Meyer, SW, JW Ingram, and GP Grabas. 2006. The marsh monitoring program: evaluating marsh bird survey protocol modifications to assess Lake Ontario coastal wetlands at a site-level. Technical Report Series 465. Canadian Wildlife Service, Ontario Region, Ontario.

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

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

Panci et al. 2017. Influence of local, landscape, and regional variables on Sedge and Marsh Wren Occurrence in Great Lakes Coastal Wetlands. Wetlands: in press.

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

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

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

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

Uzarski, D.G., T.M. Burton, and J.J.H. Ciborowski. 2008. Chemical/Physical and Land Sue/Cover Measurements, in Great Lakes Coastal Wetlands Monitoring Plan, T.M. Burton, et al. (editors), Great Lakes Coastal Wetland Consortium Final Report to Great Lakes Commission (GLC) and U.S. Environmental Protection Agency – Great Lakes National Program Office (EPA-GLNPO). www.glc.org/wetlands (March 2008).

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.