Great Lakes Coastal Wetland Monitoring Program

Semiannual Progress Report

April 1, 2019 – September 30, 2019

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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

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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 one, 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 are now completing the second round of this monitoring. The status of the effort has been changed from a project to a sampling program, and we are working on the second complete round of coastal wetland sampling. During this second round (2016-2020) we are investigating adjustments to our indicators to deal with the effects of water level fluctuations and the very high water levels that the Great Lakes are experiences. In addition, we continue to support wetland restoration projects by providing data, information, and context.

Summary 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. Anuran 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. Our project management team has not changed.

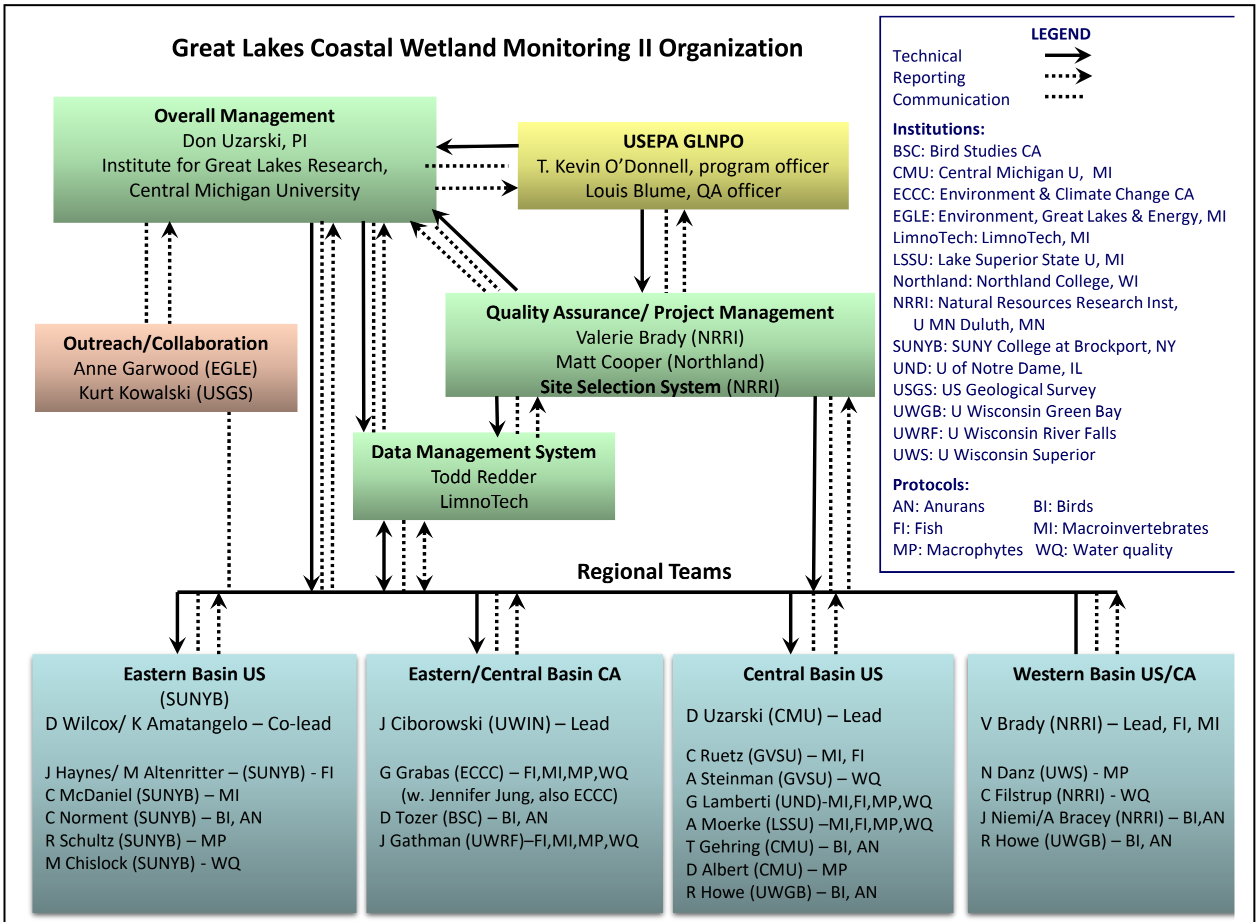

Figure 1. Organizational chart for the program showing lines of technical direction, reporting, and communication separately.

PROGRAM TIMELINE

The program timeline remains unchanged and we are on-schedule (Table 1). During the next project period we will process all remaining samples collected this summer, identify the macroinvertebrates and remaining macrophytes, enter all data and QC it, and generate the metrics and indicators for each taxonomic group and water quality.

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

	‘15	**2016**				**2017**				**2018**				**2019**				**2020**			
Tasks	**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

Work on this project will extend beyond the project period if the wetlands sampled during the summer of 2020 are to have their data completely entered and QC’d and metrics and indicators generated to indicate condition of the sampled biotic groups and water quality. This process takes until the spring of the next year (e.g., 2021). We will request an amendment in 2020 in consultation with our project officer.

GLRI Action Plan II of Measure of Progress

GLRI Action Plan II of Measure of Progress		Reporting Period (April 1, 2019 – September 30, 2019)	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	212*	75%

* Number assessed during this reporting period. See Table 5 for total wetlands assessed in this project period.

SITE SELECTION

Year nine site selection was completed in March 2019. Because we completed the original Coastal Wetland Monitoring site list in 2015 (year 5), we are now going through that list again, according to the experimental design. In 2016, we sampled the same site list as was generated for 2011. This summer we sampled the sites sampled in 2014. 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. The dramatic change in Great Lakes water levels has also affected what wetlands we are able to sample for which biota. This has also resulted in differences in sites sampled between 2014 and 2019.

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 hectares, had herbaceous vegetation, and had (or appeared to have) a lake connection navigable by fish, and lake influence 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).

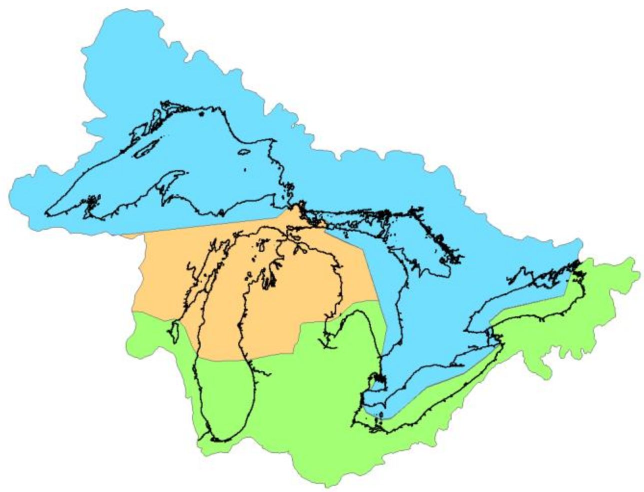

Figure 2. Divisions of lakes into regions. Note that stratification is by region *and* lake, so northern Lake Erie is not in the same region as Lake Superior, etc.

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 2018, when panel *C* was sampled for the second time, the 21 sites in sub-panel *b* of panel *B* were 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 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.

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.

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

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.

2019 Site Selection

For 2019, 243 sites were selected for sampling. Of these, 28 were benchmark sites. Another 20 sites were resample sites and 20 were pre-sample sites, which will be resample sites next year (2020). 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, anurans, 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, including in-person training by the management team, as necessary when major personnel changes take place (e.g., new field crew chief, new PI). 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 (2019): 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 anuran field crews includes tests on anuran 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 and was done in both 2017 and 2018 as new staff joined the program.

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 anuran 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 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 and macronvertebrates, anurans, and birds. Separate data entry/editing forms are created for data entry based on database table schema information that is also stored the PostgreSQL database. Data entry/editing forms are password-protected and can only be accessed by users that have "Project Researcher" or "Admin" credentials associated with their CWMP user account and permissions for specific taxa group(s).

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 anuran and bird groups who use dual-entry for quality assurance;
- Tools for adding new taxa records or editing existing taxa records for the various taxonomic groups; and
- GPS waypoint file (*.gpx) uploading utilities and waypoint processing to support matching of geographic (latitude/longitude) coordinates to sampling points.

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 from state management agencies are able to access the separate download pages for raw data and custom queries. Such organizations include GLNPO and its subcontractors and EGLE (formerly MDEQ). Index of Biological Integrity (IBI) metrics are currently included as a download option based on static scores that reflect data collection through the 2018 field season. Over the past two years, a standalone .NET-based program has been developed and fully tested to automate the calculation of IBI metric scores for vegetation, invertebrates and fish on an annual (spring) schedule after data have been entered and gone through QA/QC.

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). Currently, datasets for the major taxonomic groups must be downloaded individually; however, a comprehensive export of all pertinent data tables is generated in a single MS Access database file and provided to GLNPO on a semi-annual schedule in fall and spring of each program year.

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 addition 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 GLRI. CWMP data management support staff generate and provide to GLNPO and GDIT contractors 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.

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 are 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. To complement the full system backup, complete backups of the CWMP PostgreSQL database and the companion user database are created independently of the Veeam backup each night at 3:00 AM Eastern time, using a scheduled backup with the PostgreSQL Backup software application. A database upload task scheduled through the Windows Task Scheduler then uploads the files to a Sharefile site maintained by LimnoTech, where files are retained for a minimum period of 30 days. Backups associated with the semi-annual database release to GLNPO are permanently retained on LimnoTech's corporate network. The database backup protocol allows for isolated restoration of only the database files should any data become corrupted or otherwise compromised.

RESULTS-TO-DATE (2011-2018, with exceptions 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 nearly completed 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, 209 wetlands in 2017, 192 wetlands in 2018, and 211 wetlands in 2019.

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).

Table 5. Counts, areas, and proportions of Great Lakes coastal wetlands sampled in Round 1 (2011 – 2015) and Round 2 (2016 – 2020) sampling by the Coastal Wetland Monitoring Program. 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%	7,801	20%
2018	67	35%	3,356	18%
2019	76	36%	7,746	20%
CA total Round 2	**276**	**34%**	**23,444**	**18%**
United States				
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%
2018	125	65%	17,715	82%
2019	135	64%	30,281	80%
US total Round 2	**528**	**66%**	**103,538**	**82%**
Overall Totals Round 1	**1010**		**151,446**	
Overall Totals Round 2	**804**		**126,982**	

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 Great Lakes coastal 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.

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.). In 2017 Lake Ontario levels reached highs not seen in many decades. Water levels were again near historic highs in 2019 and crews continued to report sampling challenges due to the high water, with coastal wetlands flooded out and only beginning to migrate upslope into areas that remain covered by terrestrial vegetation (shrubs, trees, etc.) or being blocked in this upslope migration by human land use or shoreline hardening. 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 2019 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 anurans typically were sites that were impossible to access safely, and often related to private property access issues. Most bird and anuran 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 anuran 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.

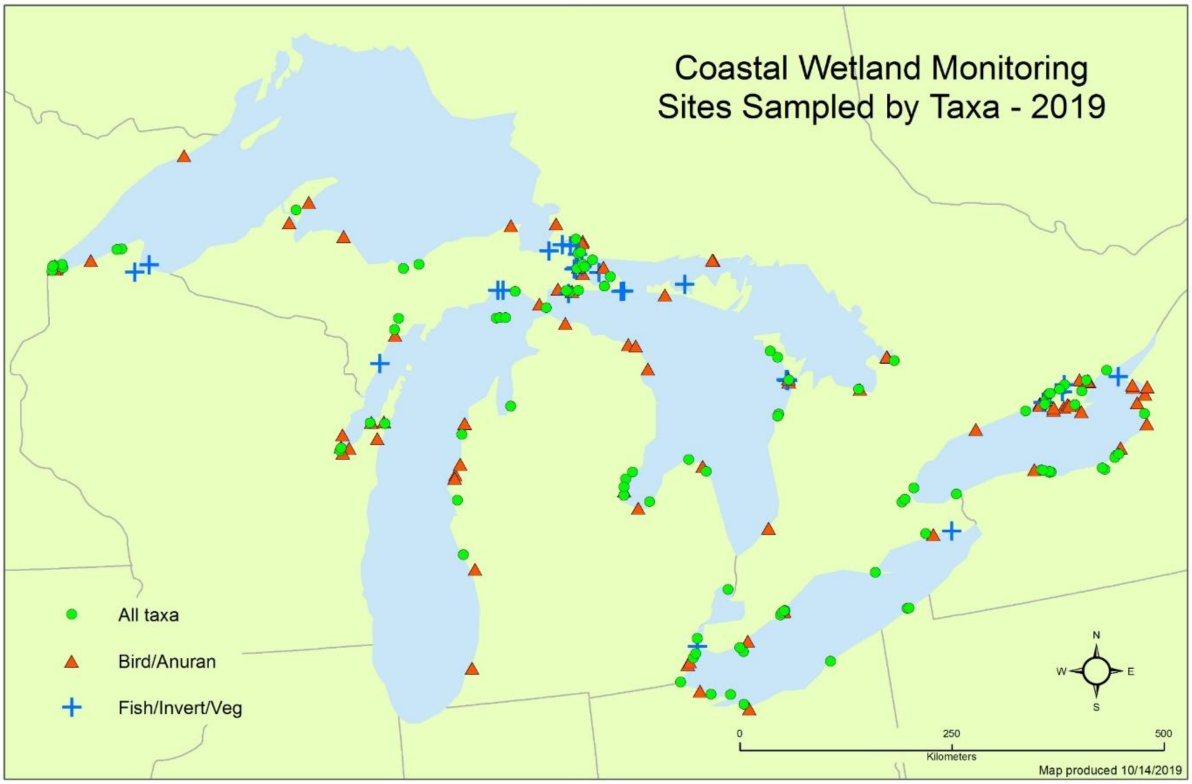

Figure 3. Locations of the 211 Great Lakes coastal wetlands sampled in 2019, color-coded by taxonomic groups. Sites assigned only to bird and anuran crews (due to their greater sampling capacity) are shown with a red triangle.

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 since 2014 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 more than 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. 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. Almost all benchmark sites are in the US.

Determining whether Benchmark sites would have been sampled at some point as part of the random site selection process is somewhat difficult because some of the exclusion conditions are not easy to assess without site visits. Our best estimate is that approximately 60% of the 17 benchmark sites from 2011 would have been sampled at some point, but they were marked "benchmark" to either sample them sooner (to get ahead of restoration work for baseline sampling) or so that they could be sampled more frequently. Thus, about 40% of 2011 benchmark sites were either added new because they are not (yet) wetlands, are small, or were missed in the wetland coverage, or would have been excluded for lack of connectivity. This percentage decreased in 2012, with only 20% of benchmark sites being sites that were not already 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.

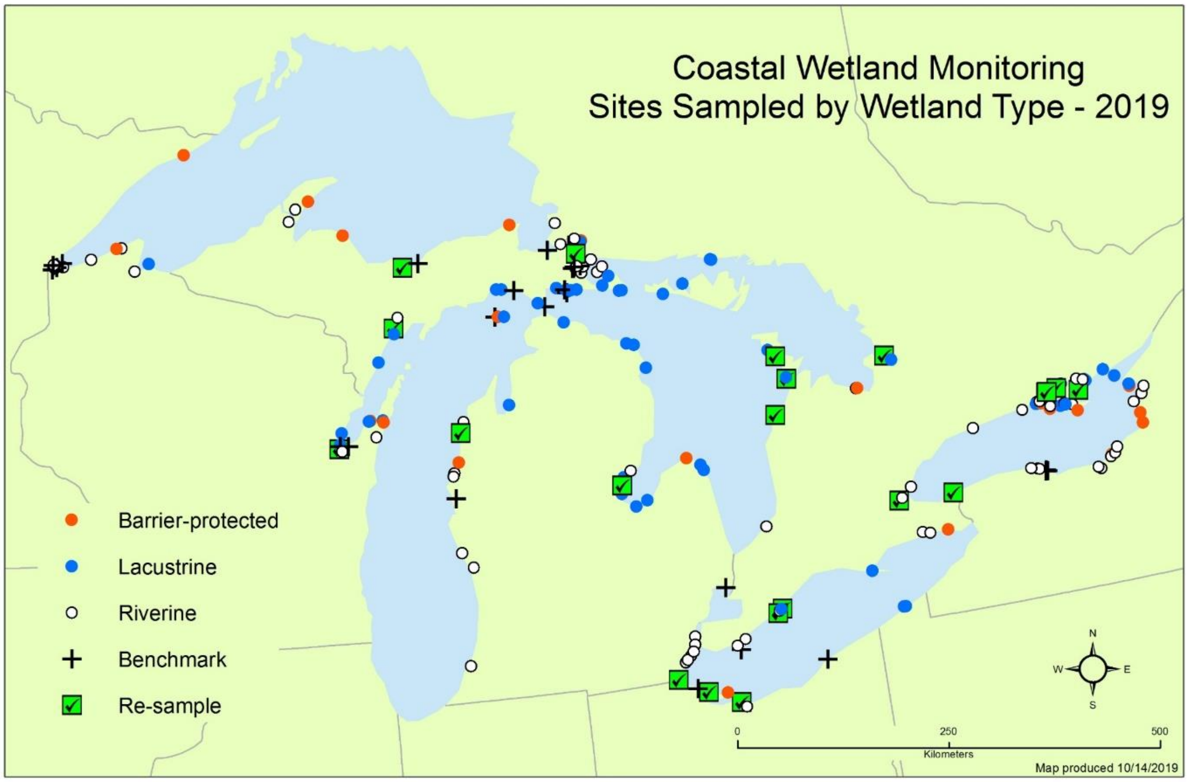

Figure 4. Locations of the 192 Great Lakes coastal wetlands sampled in 2018, color-coded by site type. Wetland types exhibit a clumped distribution across lakes due to geology and topography.

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 are from 2018 and will be updated again in the spring of 2020.

Wetlands contained approximately 25 bird species on average; some sampled benchmark sites had no birds detected, but richness at high quality sites was as great as 60 bird species (Table 6). There are many fewer calling amphibian species (anurans) in the Great Lakes (10 total), and coastal wetlands averaged about 4 species per wetland, with some benchmark wetlands containing no anurans (Table 6). However, there were wetlands where 8 anuran species were heard over the three sampling dates.

Table 6. Bird and calling amphibian species (anurans) in wetlands; summary statistics by country. Data from 2011 through 2015.

Country	Site count	Mean	Max	Min	St. Dev.
Birds					
Can.	487	28.6	64	4	10.4
U.S.	935	23.2	60	0	11.0
Anurans					
Can.	487	4.5	8	0	1.8
U.S.	874	3.9	8	0	1.5

Bird and anuran 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 Huron, with Lake Michigan a close second, followed by Erie and Superior. These data include the benchmark sites, many of which are in need of restoration, so the minimum number of species is quite low for some of these wetlands.

Anuran species counts show less variability among lakes simply because fewer of these species occur in the Great Lakes. Wetlands averaged three to nearly five anuran 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 anurans were detected.

Table 7. Bird and anuran species found in Great Lakes coastal wetlands by lake. Mean, maximum, and minimum number of species per wetland for wetlands sampled from 2011 through 2018.

	Birds				Anurans			
Lake	Sites	Mean	Max	Min	Sites	Mean	Max	Min
Erie	183	26.2	54	4	171	3.6	7	0
Huron	437	24.9	64	2	415	4.1	8	0
Michigan	240	25.7	60	1	224	3.8	7	0
Ontario	265	23.4	54	7	370	4.7	8	1
Superior	193	26.5	52	10	177	3.8	8	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.	255	10.0	23	2	3.9
U.S.	564	12.9	28	2	5.1
Non-natives					
Can.	255	0.7	4	0	0.9
U.S.	564	1.0	6	0	1.0

Looking at the data from all wetlands sampled, 2011 through 2018, we caught no non-native fish in 40% of Great Lakes coastal wetlands sampled, and we caught only one non-native fish species in 39% of these wetlands (Figure 5). We caught more than one non-native fish species in far fewer wetlands. 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.

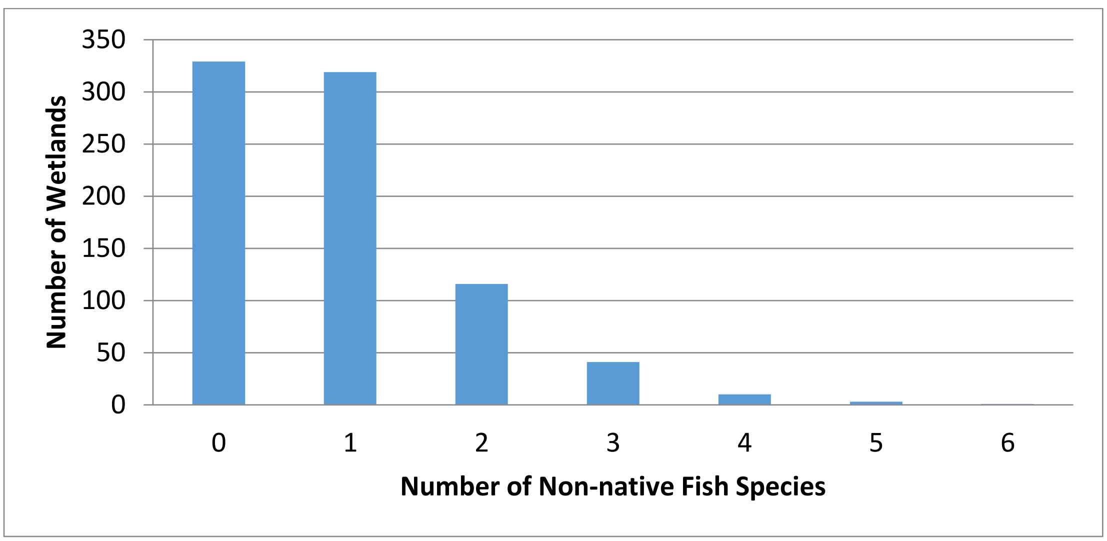

Figure 5. Number of Great Lakes coastal wetlands with non-native fishes. Data from 2011 - 2018.

Total fish species did not differ greatly by lake, averaging 11-13 species per wetland (Table 9). Lake Ontario wetlands had the lowest maximum number of species (23), with the other lakes all having similar maximums of 27-28 species. Because 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 (0.6 species per wetland), and Lake Erie wetlands had the highest, averaging 1.5 non-native fish species per wetland. 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. Having very few or no non-native fish is a positive and all lakes had some wetlands in which we caught no non-native fish. This result does not necessarily mean that these wetlands are completely free of non-native fishes. Our single-night net sets do not always detect all fish species in a wetland and some species are quite adept at avoiding passive capture gear. For example, common carp are known to avoid fyke nets. There are well-documented biases associated with each type of fish 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 2018.

		Fish (Total)			Non-native		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	105	11.3	27	2	1.5	5	0
Huron	277	11.6	27	2	0.6	3	0
Michigan	127	12.9	28	4	1.0	5	0
Ontario	201	11.7	23	4	0.9	4	0
Superior	105	13.3	28	3	1.0	6	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. 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 2018.

Country	Sites	Mean	Max	Min	St. Dev.
Overall					
Can.	297	38.2	76	13	11.9
U.S.	632	39.6	86	12	13.0
Non-natives					
Can.	297	0.6	4	0	0.9
U.S.	632	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 and Erie having lower averages than the upper lakes (Table 11). The maximum number of invertebrate taxa was higher in lakes Huron and Michigan wetlands (>79) 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. 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 2018.

		Macroinvertebrates (Total)			Non-native		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	113	34.9	69	12	0.9	4	0
Huron	321	42.2	79	13	0.7	5	0
Michigan	144	41.25	86	17	0.8	3	0
Ontario	222	33.4	62	13	0.8	4	0
Superior	124	42.9	69	15	0.2	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.

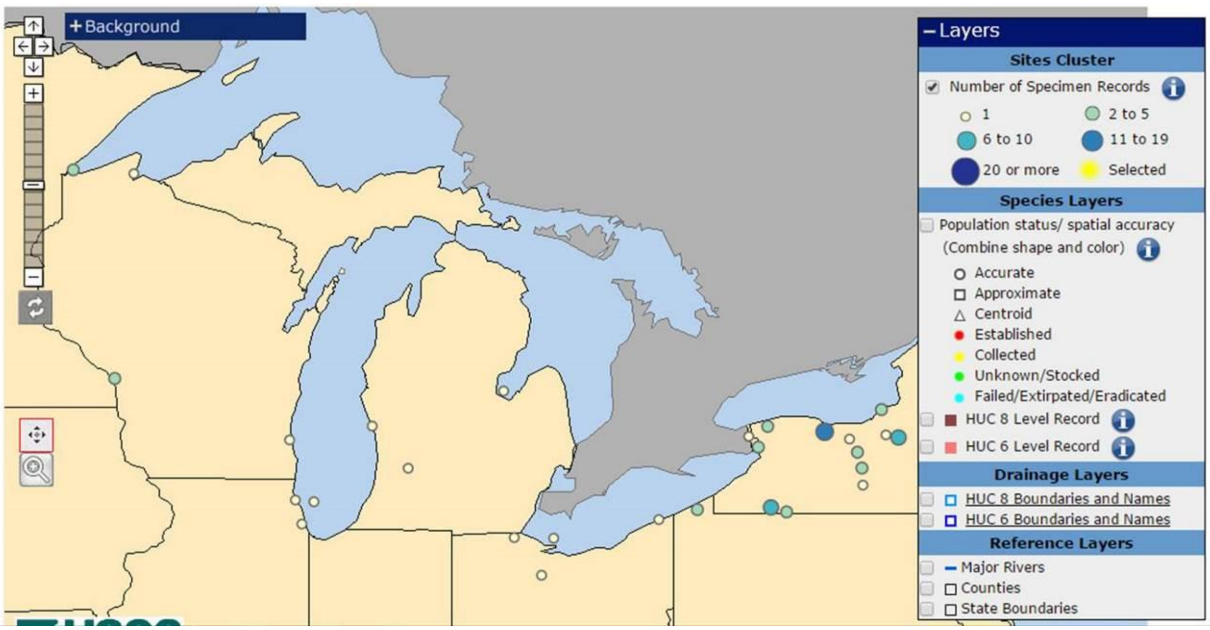

Figure 6. Locations of *Bithynia tentaculata* in USGS NAS website PRIOR to our project providing additional locations where they were collected.

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).

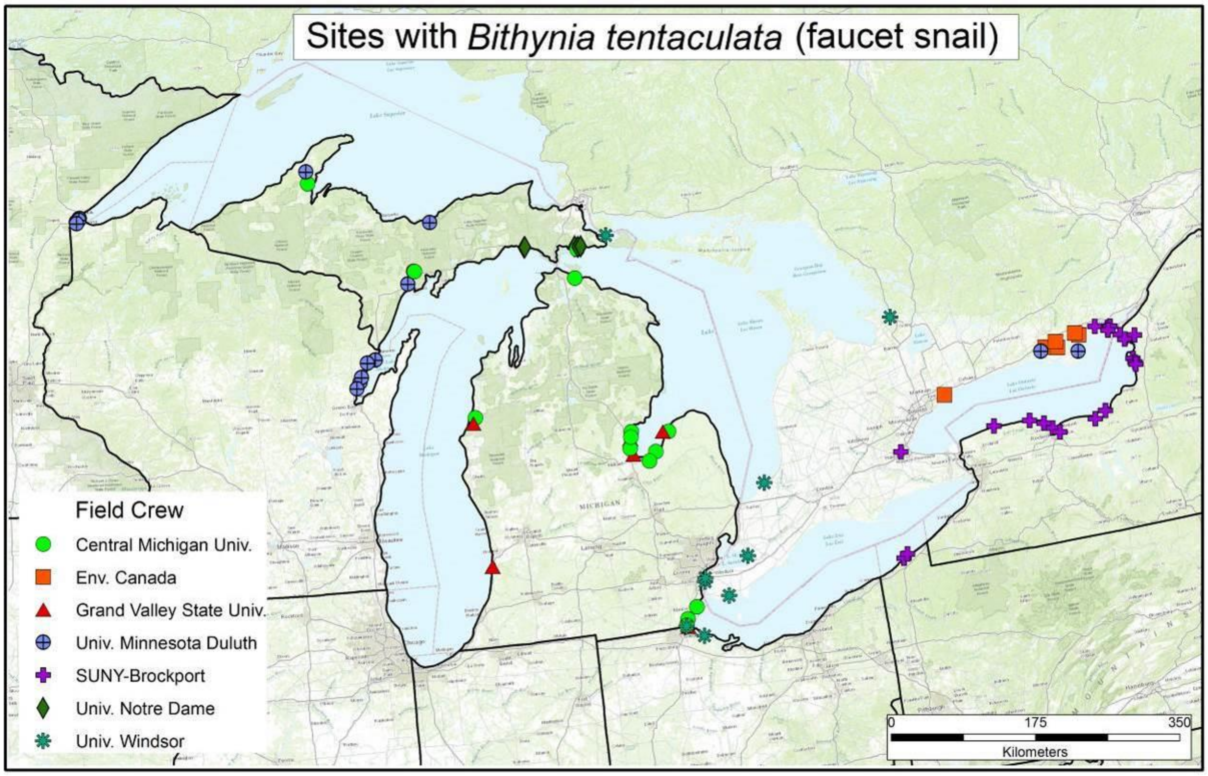

Figure 7. Locations of *Bithynia tentaculata* found by CWM crews, 2011 - 2013.

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.

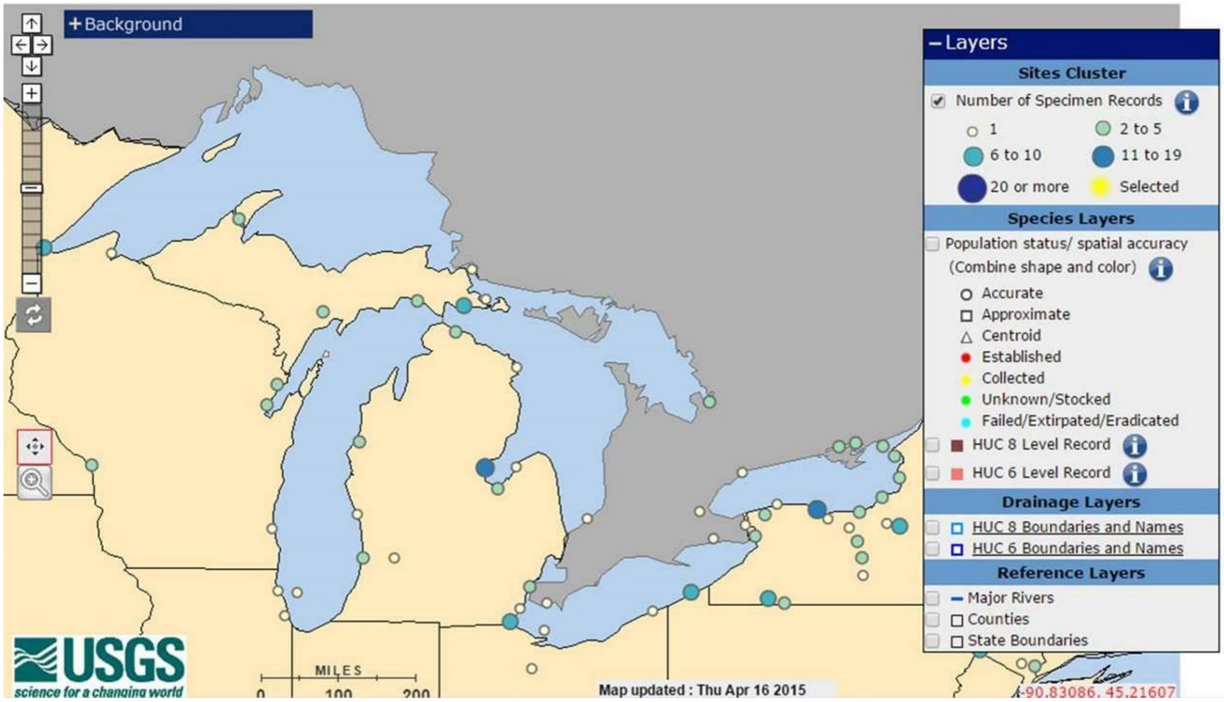

Figure 8. Locations of *Bithynia tentaculata* in USGS NAS website AFTER our project provided additional locations where they were collected; compare to Figure 6.

On average, there were approximately 42 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 13 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 2018 for total species and invasives; data from 2011-2015 for US at-risk species.

Country	Site count	Mean	Max	Min	St. Dev.
Overall					
Can.	317	41.7	87	6	16.5
U.S.	637	42.0	100	1	17.0
Invasives					
Can.	317	3.6	11	0	2.0
U.S.	637	3.5	13	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 through 2015, 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 (9-13 species). All lakes had some wetlands in which no invasive plants were found.

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 2018.

		Macrophytes (Total)			Invasives		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	124	25.5	69	1	4.4	13	0
Huron	333	48.9	100	4	2.9	12	0
Michigan	136	46.0	83	4	3.7	9	0
Ontario	234	40.0	87	8	5.0	12	0
Superior	123	39.2	78	2	1.3	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 954 sampled wetlands lacked invasive species, leaving 91% with at least one. Sites were most commonly invaded by 1 – 5 invasive plant species and 10% 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.

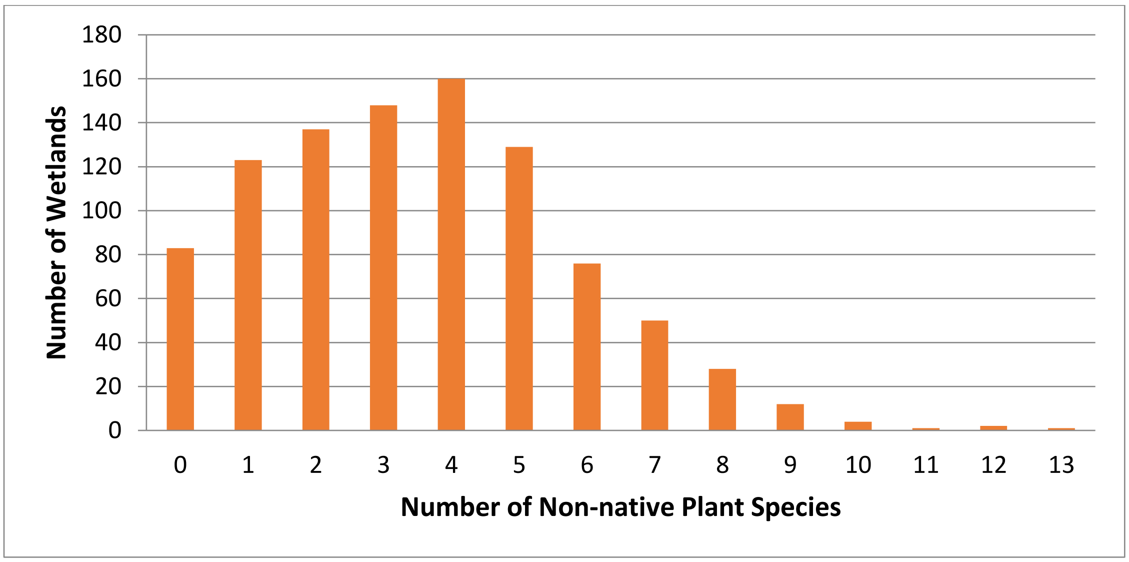

Figure 9. Number of Great Lakes coastal wetlands containing invasive plant species based on 2011 through 2018 data.

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.

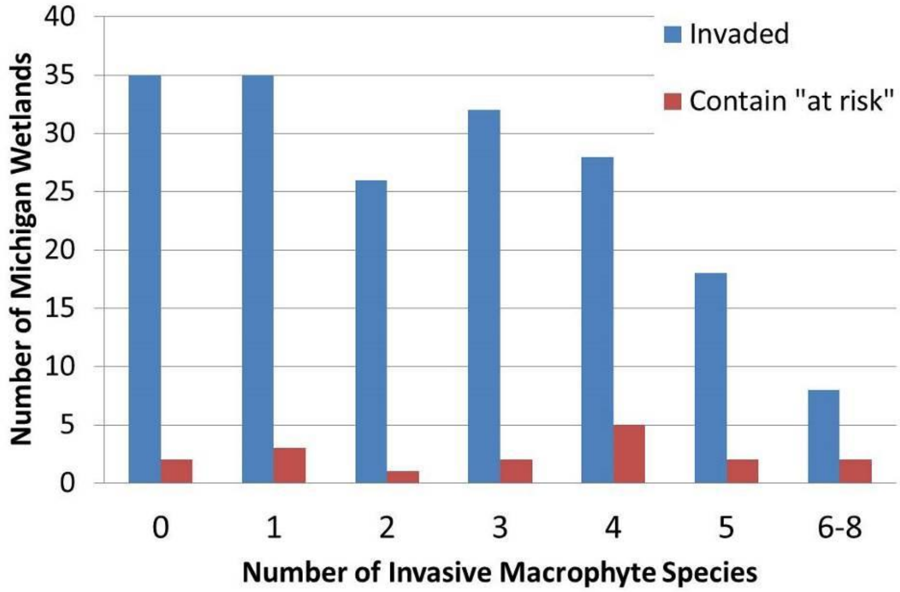

Figure 10. Number of state of Michigan Great Lakes coastal wetlands containing both invasive plant species and “at risk” plant species, based on 2011 through 2014 data.

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.

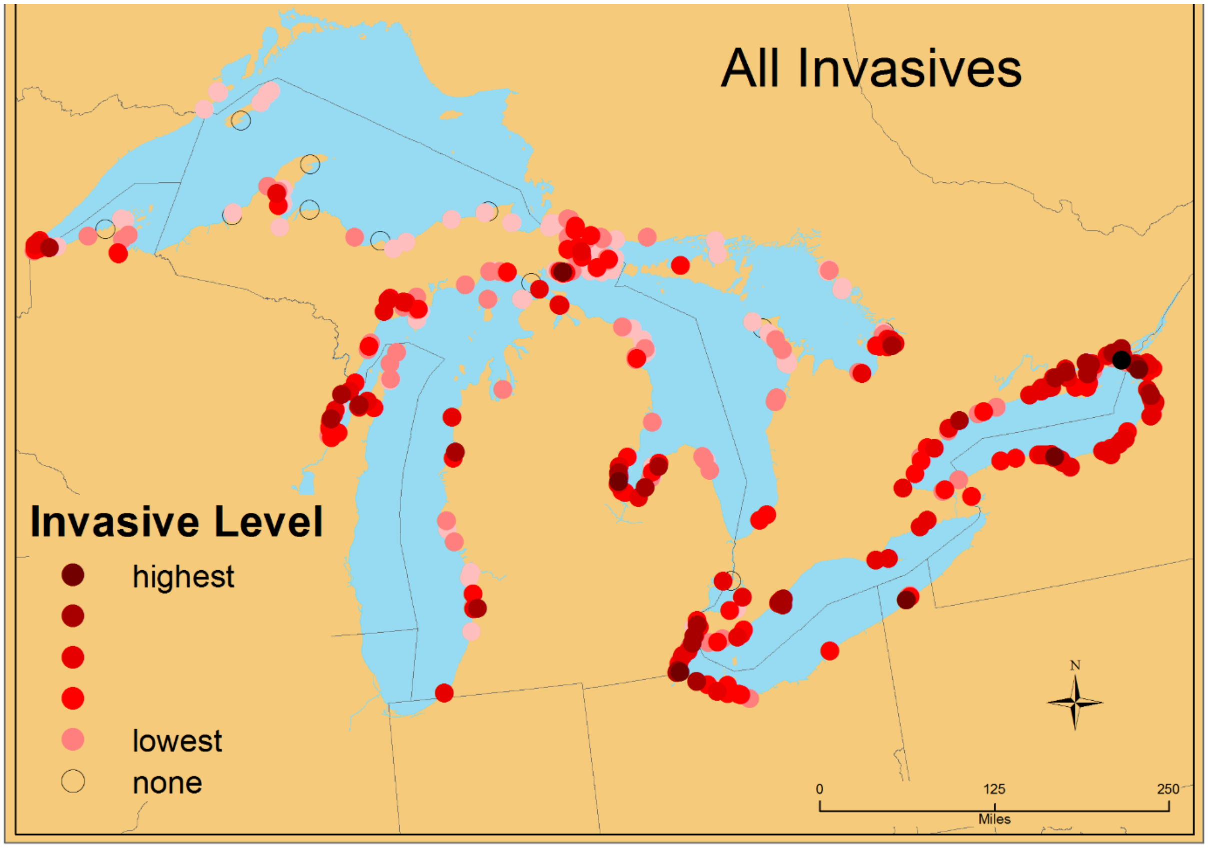

Figure 11. Level of “invadedness” of Great Lakes coastal wetlands for all non-native taxa combined across all taxonomic groups, based on data from 2011-2014.

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 anurans).

Macrophytic vegetation has been used for many years as an indicator of wetland condition (only large plants; algal species were not included). 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.

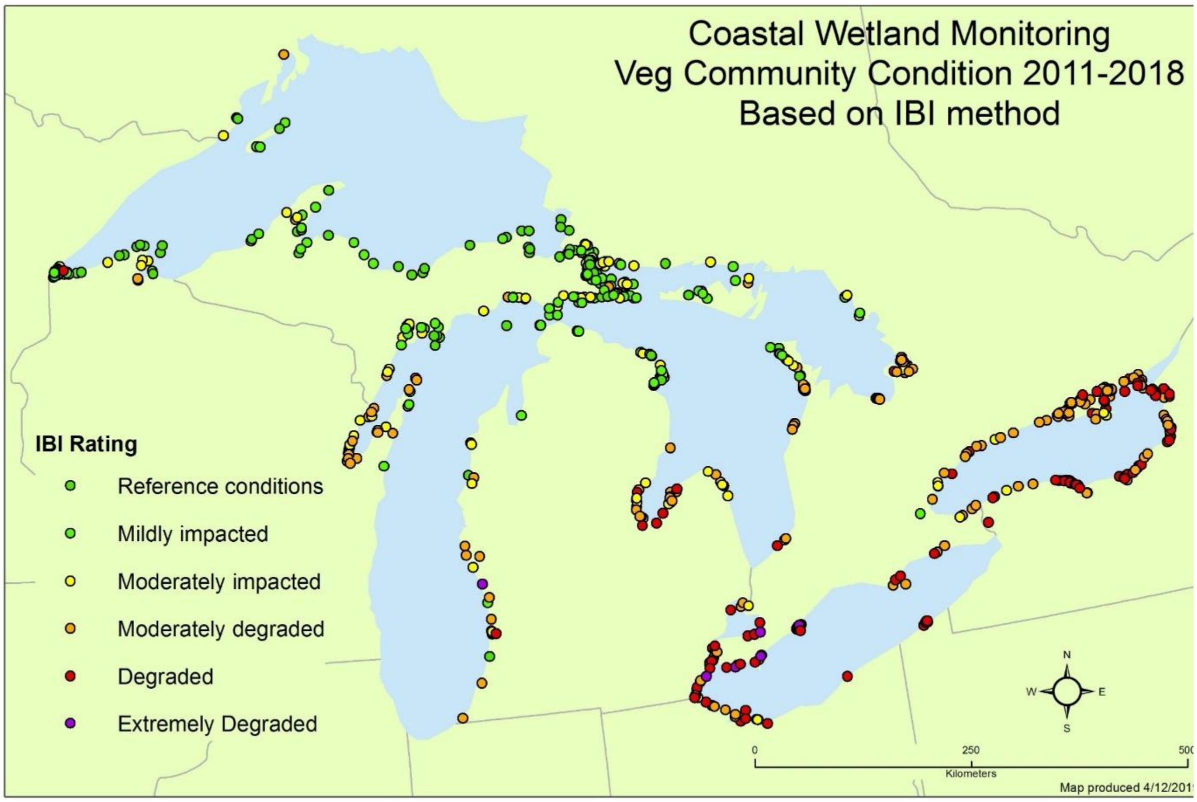

Figure 12. Condition of coastal wetland vegetation at sites across the Great Lakes. Circle color indicates vegetation community quality. The indicator is labeled “draft” while this indicator is investigated for robustness against varying water levels and latitude. Based on data from 2011 through 2018.

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 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. This year we had a major shift in the taxonomy of some invertebrates (primarily snails and mollusks) used in the calculation of some indicator metrics due to taxonomic updates and revisions. Thus, the invertebrate IBI map (Figure 13) in this report should not be compared to the maps shown in previous reports. However, this IBI has been calculated for all sites with appropriate zones and invertebrate data for all years.

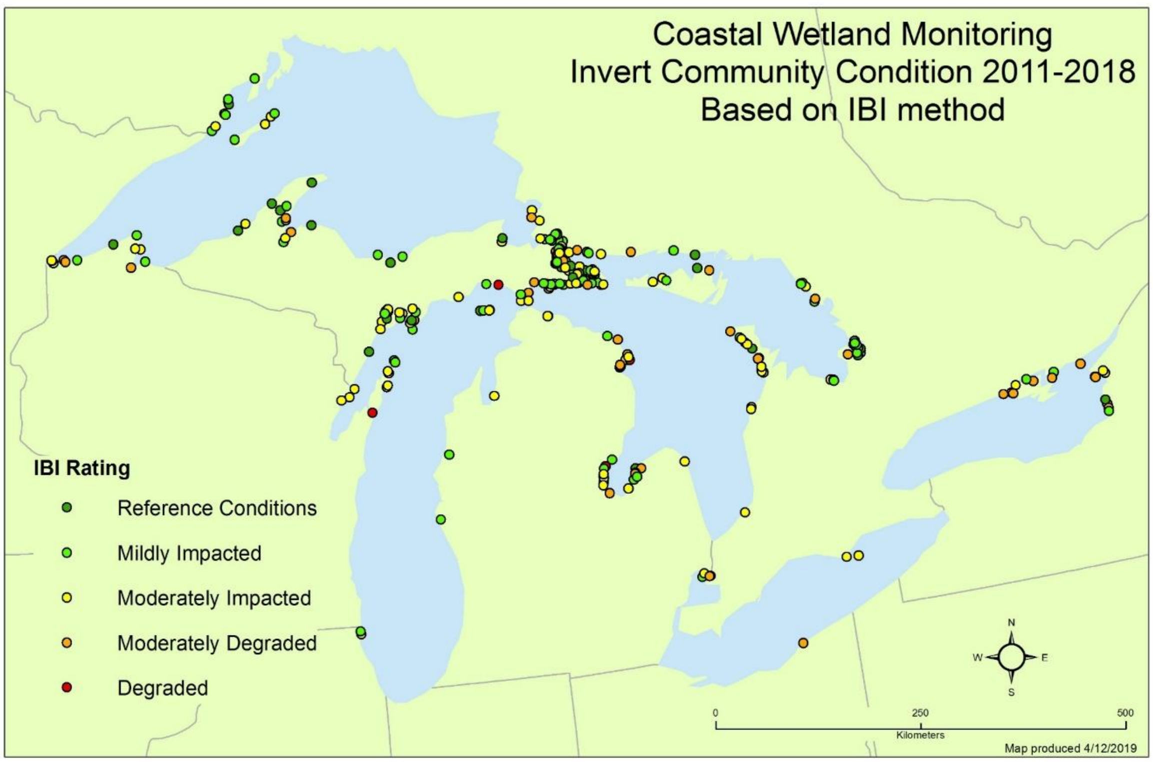

Figure 13. Condition of coastal wetland macroinvertebrate communties at sites with bulrush or wet meadow zones. The indicator is labeled “draft” while more zone IBIs are calculated. Based on data from 2011 through 2018.

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 now able to report updated and improved fish IBI scores for wetland sites containing bulrush, cattail, lily, or SAV zones (Figure 14). Because of the prevalence of these vegetation types in wetlands throughout the Great Lakes basin, this indicator provides more site scores than the macroinvertebrate indicator. Because these are updated and adjusted indicators, the map image in this report should not be compared to fish IBI map images in previous reports. However, all sites reporting fish data from zones applicable to the new fish IBIs are shown here, regardless of the year they were sampled.

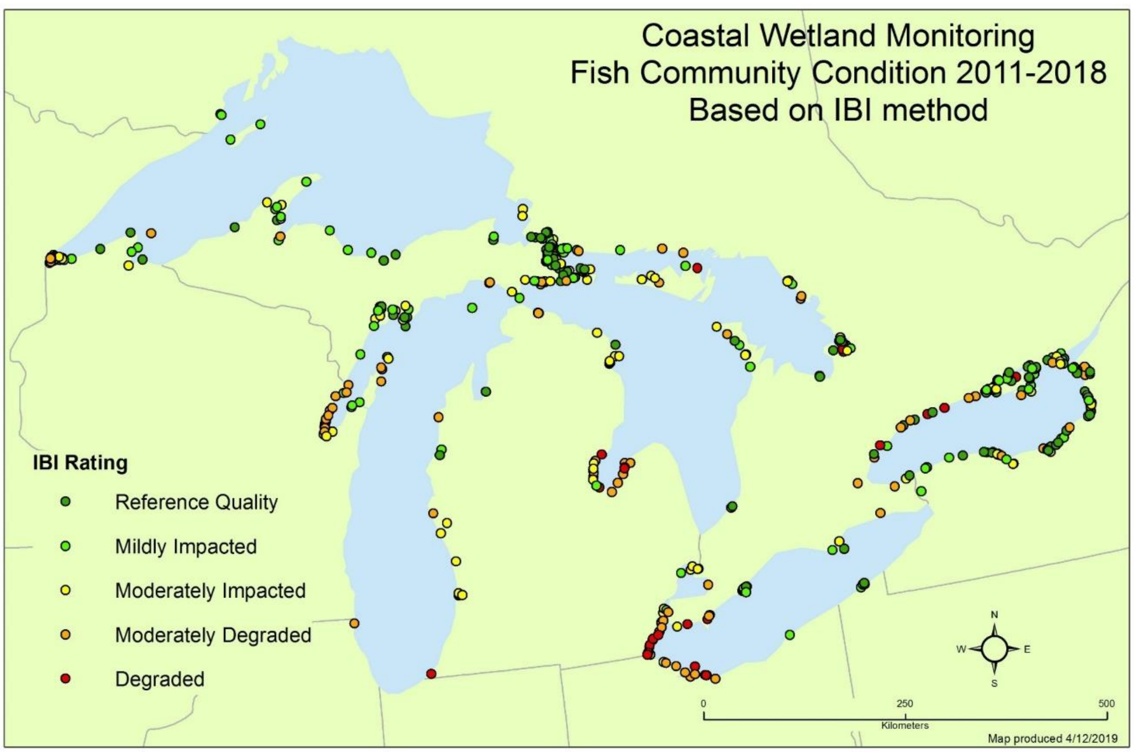

Figure 14. Condition of coastal wetlands based on fish communties at sites with bulrush, cattail, water lily, and submerged aquatic vegetation zones. Based on data from 2011 through 2018.

To develop the new fish IBI, fish community 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 (SumRank; 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 (2011-2015 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 10-11 fish assemblage 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 five years. A manuscript describing development and testing of this IBI has been published (Cooper *et al.* 2018).

Significant progress was made during 2017-18 in developing multispecies indicators for birds and anurans. Coastal wetlands were scored on a scale ranging from 0 (worst condition) to 10 (best condition) by a transparent indicator known as the Index of Ecological Condition (IEC). This metric, first described by Howe et al. (2007a,b) and improved by Gnass-Giese et al. (2015), uses maximum likelihood estimation of condition based on the documented responses of species to an independently-derived environmental reference gradient (BR functions). The response variable for both birds and anurans was probability of occurrence, equivalent to the frequency of occurrence among "bins" of sample points with similar reference condition. The shapes of the Gaussian BR curves are directly dependent on the nature of the environmental reference/stressor gradient. Parameters (mean, standard deviation, and height parameter) were estimated by computer iteration in R version 3.4.4 (R Core Team 2018) using a package (iec) developed by N. Walton and R. Howe. A foundation for estimating confidence intervals around IEC estimates was developed recently by Gaul (2017).

New IEC estimates in 2018 are the result of several Improvements in the analytical framework:

1. An improved reference gradient was available through the work of Panci *et al.* (2017). This research provided more detailed landscape variables for 549 unique wetland points. Watershed data from Danz *et al.* (2007) was combined with Panci *et al.*'s data to yield 35 variables (31 GIS variables such as percent emergent wetland within 500 m, percent road right-of-way within 2000 m; plus 4 Danz *et al.* (2007) variables including population density and percent agricultural land within the wetland's contributing watershed). Many of these variables were strongly correlated, so the list was reduced to 17 variables with Pearson's $r < 0.70$. A principal component analysis (PCA) was used to further reduce these variables to a single gradient. The first three PCA axes were interpretable in terms of environmental stressors. The first axis, accounting for 22.4% of the variation, was negatively correlated with percent developed land within 100 m, watershed population density, and watershed rural land use; and positively correlated with percent forest within 1000 m and % wooded wetland within 1000 m. The second axis, accounting for 14.1% of the variation, was negatively correlated with percent cropland within 1000 m and positively correlated with percent total wetland within 500 m and percent emergent wetland within 500 m. The third axis, accounting for 11.4% of the variation, was negatively correlated with percent cropland within 1000 m and percent agricultural land within the watershed, and positively with percent forest within 1000 and percent inland water within 2000 m. For each wetland point, a single environmental condition score (C_{env}) was calculated as the sum of scores weighted by the percent variation explained by each axis. The C_{env} value represents the "human footprint" associated with a given wetland site. A major feature of this new gradient was the inclusion of percent total wetland area within 500 m and percent emergent wetland within 500 m, both measures of wetland habitat availability and inverse indicators of wetland habitat loss.

2. The IEC for birds was calculated from biotic response (BR) functions for 8 marsh obligate species (e.g., Pied-billed Grebe, *Podilymbus podiceps*; American Bittern, *Botaurus lentiginosus*; Marsh Wren, *Cistothorus palustris*), 16 marsh user species (e.g., Bald Eagle, *Haliaeetus leucocephalus*; Belted Kingfisher, *Megaceryle alcyon*; Red-winged Blackbird, *Agelaius phoeniceus*), and 8 species groups such as "rails", "diving ducks", "terns", and "Alder/Willow Flycatcher". Unless included in taxonomic groups (e.g., "rails"), rare species and species rarely found in wetland habitats were excluded, resulting in an indicator metric that directly represents the bird assemblage associated with a coastal wetland.

3. The newly derived biotic response functions assume that the worst possible condition for a wetland occurs when no birds at all are present. A “bin” representing no individuals at reference condition = 0 was added to the data for calculations of BR functions, even for species that are highly tolerant of wetland degradation.

Calculations of IEC values require two steps: 1) modeling species’ responses to a quantitative reference or stressor gradient (i.e., estimating parameters for the BR functions), typically completed by prior research, and 2) calculating IEC values for new sites based on species’ occurrences at sites of interest. Parameters of BR functions for wetland birds, based on the 549 points with independent environmental reference data, provided the basis for calculating IEC values for all 2,748 point counts collected between 2011-2017 at 765 coastal wetlands. Where more than one count was conducted at a given wetland, we plotted the maximum value (Figure 15). Note that the BR functions developed for this project can be used to calculate IEC values at any new wetland site. The critical data requirement is that presence or absence is recorded for all 32 species/species groups and the survey method follows the CWMP protocol used to generate the BR functions. Because all wetland surveys are conducted in an open habitat, we assume that detectability of birds is the same among points.

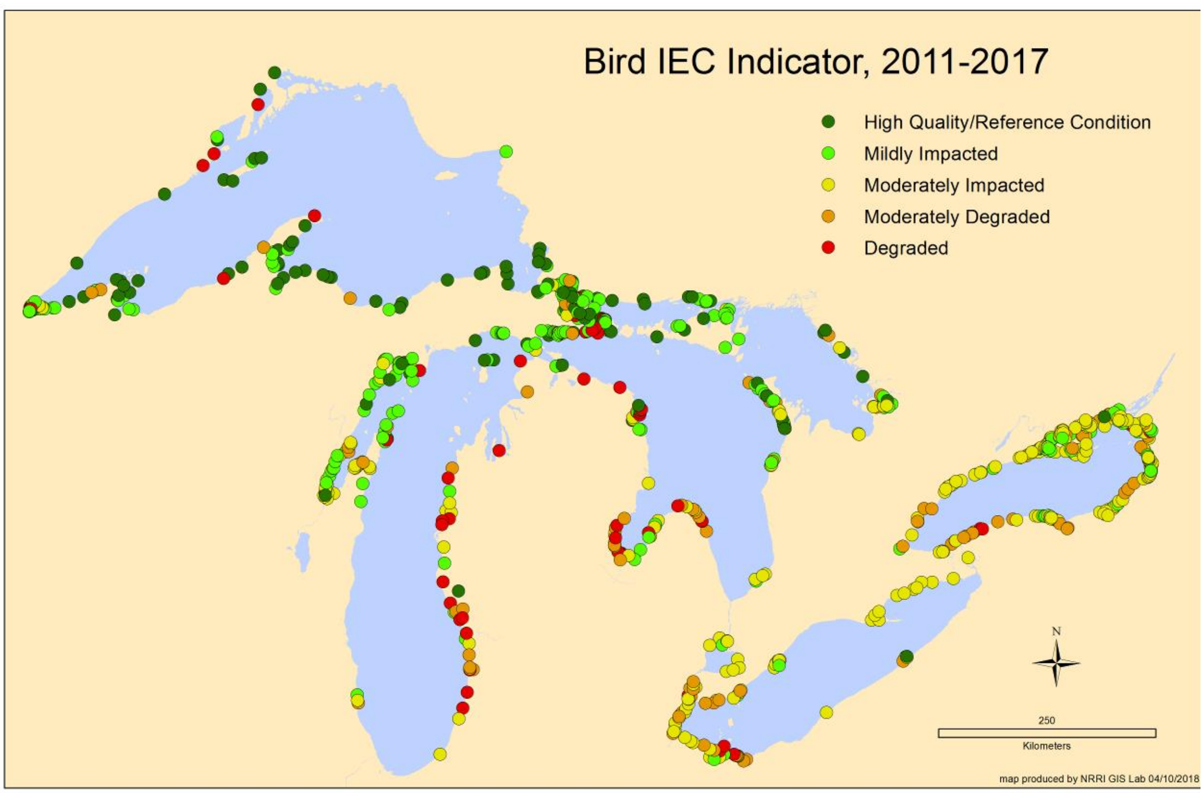

Figure 15. Condition of coastal wetland bird communties. This indicator is based on the IEC method using data from 2011 through 2017.

Starting in 2017, field observers began recording within-wetland habitat data during surveys for birds and anurans. This information, coupled with ongoing remote sensing analyses of the wetland landscapes (G. Niemi, R. Howe, G. Grabas, *pers. comm.*), will lead to an even better reference gradient, and therefore improved BR functions.

IEC scores based on birds reveal significant differences in mean IEC values among lakes ($p < 0.001$, general linear model with lake, year group, and lake*year group as predictors) and, marginally, between the two year groups ($p = 0.053$). The interaction between lake and year group was not significant ($p > 0.20$). Highest mean IEC values were recorded in Lake Superior and Lake Huron, whereas lowest values were recorded at Lake Erie wetlands (Table 14). Increases in IEC values were recorded between low water (2011-2014) and high water (2015-2017) years in Lake Michigan, Lake Huron, and Lake Erie. Little change occurred in Lake Ontario, while in Lake Superior the mean IEC actually dropped between 2011-14 and 2015-2017.

Table 14. Mean Index of Ecological Condition (IEC) for breeding birds at 765 coastal wetlands in the Great Lakes (n = 1,061 point counts or point count averages at each wetland; standard errors are shown in parentheses). Sites are divided into years with lowest water levels (2011-2014) and years with highest water levels (2015-2017). If multiple point counts were conducted at a wetland during either period (2011-2014 or 2015-2017), the average IEC was used to avoid pseudo replication.

Lake	2011-2014	2015-2017
Superior	6.77 (0.34)	6.53 (0.35)
Michigan	5.32 (0.31)	5.94 (0.21)
Huron	5.80 (0.22)	6.14 (0.21)
Erie	4.03 (0.21)	4.94 (0.16)
Ontario	5.10 (0.11)	5.11 (0.11)

The same environmental reference gradient (C_{env}) was used to generate BR functions for anurans. Coastal Wetland Monitoring field teams have recorded 13 species of anurans (2 toads and 11 frogs) since 2011, but 4 of these (northern [Blanchard's] cricket frog, *Acris crepitans*; Fowler's toad, *Anaxyrus fowleri*; mink frog, *Lithobates septentrionalis*; and pickerel frog, *Lithobates palustris*) were seldom observed and provided inadequate numbers for this analysis. Cope's gray treefrog (*Dryophytes chrysoscelis*) and eastern gray treefrog (*Dryophytes versicolor*) are sibling species that are difficult to differentiate in the field, so we combined records into a single taxon. We also did not separate geographically distinct species of chorus frogs, *Pseudacris*. IEC calculations for anurans therefore were based on 8 taxa (gray treefrogs plus American toad, *Anaxyrus americanus*; bullfrog, *Lithobates catesbeianus*; northern leopard frog, *Lithobates pipiens*; green frog, *Lithobates clamitans*; wood frog, *Lithobates sylvaticus*; chorus frogs, *Pseudacris* spp., and spring peeper, *Pseudacris crucifer*).

Anuran IEC values were calculated for 1922 point counts at 687 coastal wetlands (Figure 16). Highest IEC values were obtained for wetlands in Lake Michigan during high water years (Table 15), although very high IEC values also were found in Lakes Superior, Huron and Michigan during low water years. Lake Erie, as with birds, yielded the lowest IEC values on average. For two of the lakes (Superior and Huron), IEC values were higher on average during low water years than during high water years. A general linear model using the Gamma family of objects (because IEC values were left skewed) showed a highly significant difference among lakes (F test, $p < 0.001$) and a significant interaction between lake and year group ($p = 0.0016$). Year group (2011-2014 vs. 2015-2017) itself was not a statistically significant factor for anurans ($p = 0.20$).

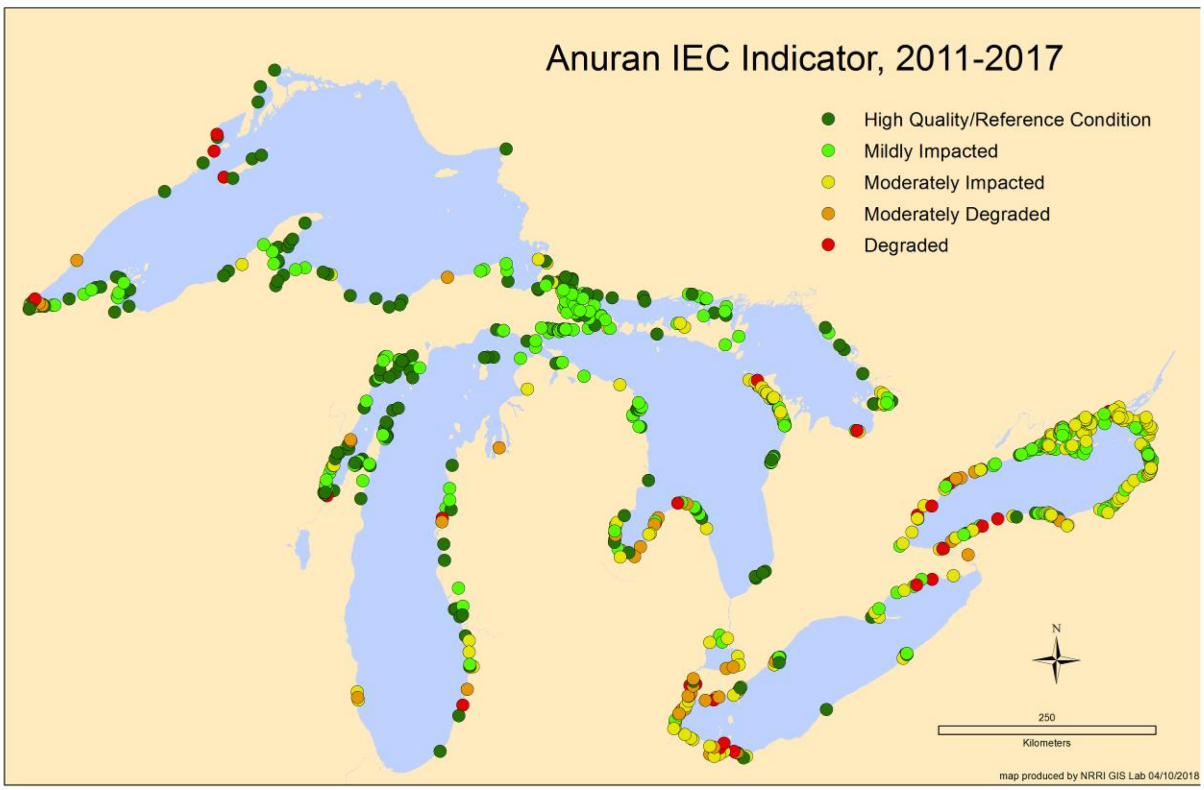

Figure 16. Condition of coastal wetland calling anuran communties. This indicator is based on the IEC method using data from 2011 through 2017.

Mean anuran species richness was highest in Lake Ontario during both low water ($\bar{x}$ = 4.12, SE = 0.10) and high water years ($\bar{x}$ = 4.65, SE = 0.13), while lowest mean species richness was recorded in Lake Erie (low water $\bar{x}$ = 2.66, SE = 0.11; high water $\bar{x}$ = 3.34, SE = 0.10). Lake Superior (low water $\bar{x}$ = 3.14, SE = 0.11; high water $\bar{x}$ = 3.72, SE = 0.13), Lake Michigan (low water $\bar{x}$ = 3.53, SE = 0.10; high water $\bar{x}$ = 3.85, SE = 0.12), and Lake Huron (low water $\bar{x}$ = 3.69, SE = 0.07; high water $\overline{x}$ = 3.93, SE = 0.09) exhibited intermediate values of species richness. Overall, most points yielded between 2-4 anuran species (Figure 17).

Table 15. Mean Index of Ecological Condition (IEC) for anurans at 687 coastal wetlands in the Great Lakes (n = 868 point counts or their averages; standard errors in parentheses). Sites are divided into years with lowest water levels (2011-2014) and years with highest water levels (2015-2017). If multiple point counts were conducted at a wetland during either period (2011-2014 or 2015-2017), the average IEC was used to avoid pseudo-replication.

Lake	2011-2014	2015-2017
Superior	7.81 (0.27)	7.61 (0.30)
Michigan	7.70 (0.29)	8.09 (0.19)
Huron	7.71 (0.14)	7.24 (0.17)
Erie	3.94 (0.28)	4.68 (0.21)
Ontario	5.94 (0.13)	6.20 (0.16)

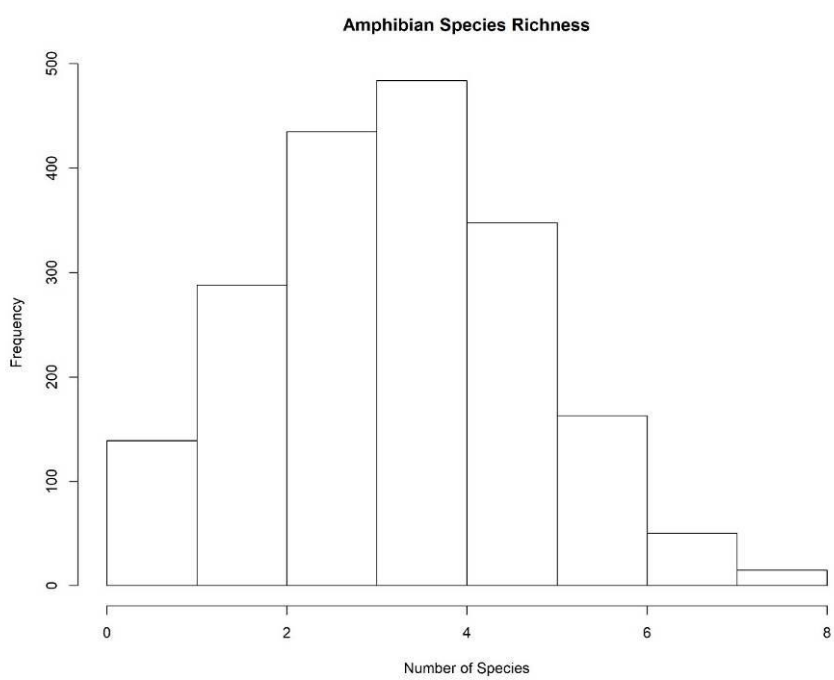

Figure 17. Distribution of species richness at coastal wetland sample points from 2011-2017. Number of species refers to the total number of species recorded during three visits to the point during a given year.

Finally, we have developed a disturbance gradient (SumRank) indicator (Harrison et al. 2019). This indicator is based on landscape stressor data, local stressor data seen at the site itself, and water quality data collected from each aquatic macrophyte plant morphotype (Figure 18). This example is based on data from 2014. Wetlands can have different scores for each plant morphotype within them because of the difference in water chemistry in different plant morphotype zones (inset a). In addition, the indicator may change over time, as indicated in Figure 18 inset b. as water quality changes from year to year. We are working to implement automated calculation of this indicator.

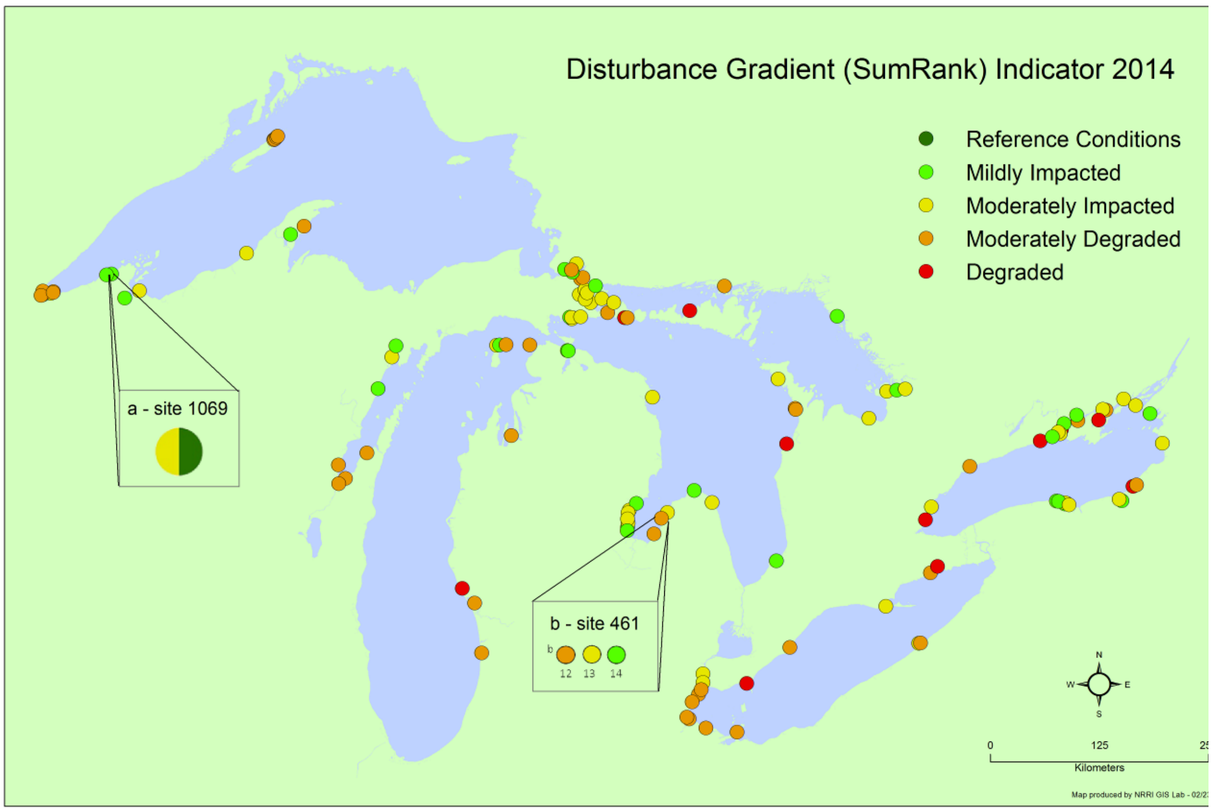

Figure 18. Disturbance gradient (SumRank) indicator. This indicator is based on landscape stressor data, site-based stressor data, and site water quality data. This example is based on data from 2014. Wetlands can have different scores for each plant morphotype within them (a), and the indicator may 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 19). 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 19. Front page of the 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:

- **<u>Public</u>** – 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;

- **Basic access (level 1)** – provides access to index of biological integrity (IBI) scores by wetland site via the coastal wetland mapping tool;
- **Basic manager and researcher access (level 2)** - access to IBI scores and full species lists by wetland site via mapping tool;
- **Advanced agency and researcher access (level 3)** - access to export tools for raw datasets (+ Level 2 capabilities);
- **CWMP researcher access (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).

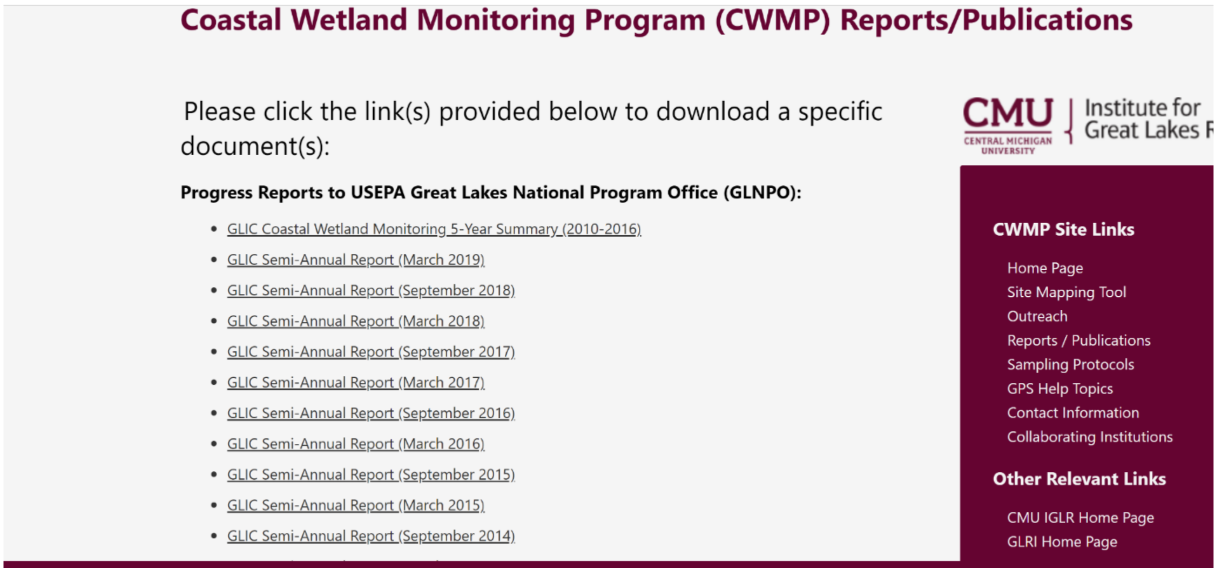

Figure 20. CWMP Reports and Publications Page.

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 Site 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 21):

- Map navigation tools (panning, general zooming, zooming to a specific site, etc.);
- Basemap layer control (selection of aerial vs. “ocean” basemaps);
- Display of centroids and polygons representing coastal wetlands that have been monitored thus far under the CWMP;

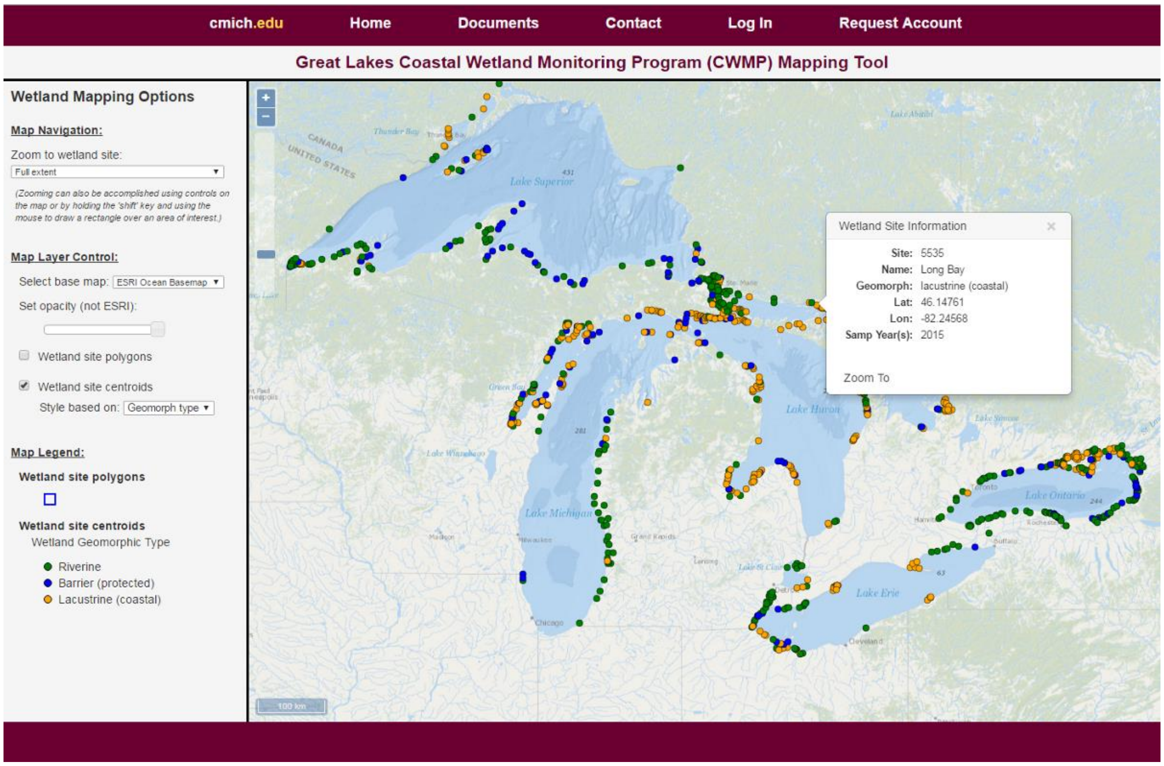

Figure 21. Coastal Wetland Mapping Tool – Public Version (geomorphic type view).

- Capability to style/symbolize wetland centroids based on: 1) geomorphic type (default view; Figure 21), or 2) year sampled (Figure 22);
- Reporting of basic site attributes (site name, geomorphic type, latitude, longitude, and sampling years) via map “pop-ups”;
- Summaries of field observations for individual sites; and
- Access to approved select digital photos collected during monitoring via a photo viewer tool.

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; Index of Ecological Condition (IEC) scores for anurans and birds, and a disturbance gradient metric based on observed site water quality conditions. “Level 1” users have access to expanded information regarding IBIs and other site conditions via the “View Site Reports” option, and they can also create customized comparison of IBI and IEC scores across select sites using the “Wetland Site Comparison” feature.

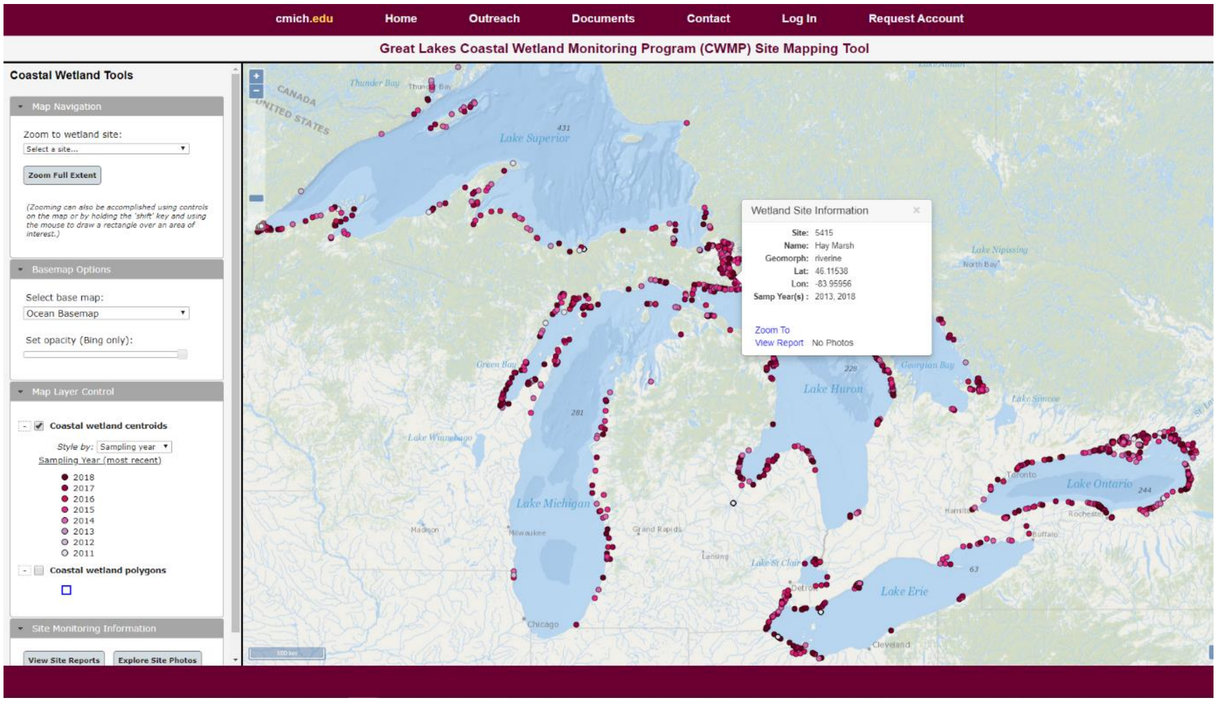

Figure 22. Coastal Wetland Mapping Tool – Public Version (sampling year view)

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

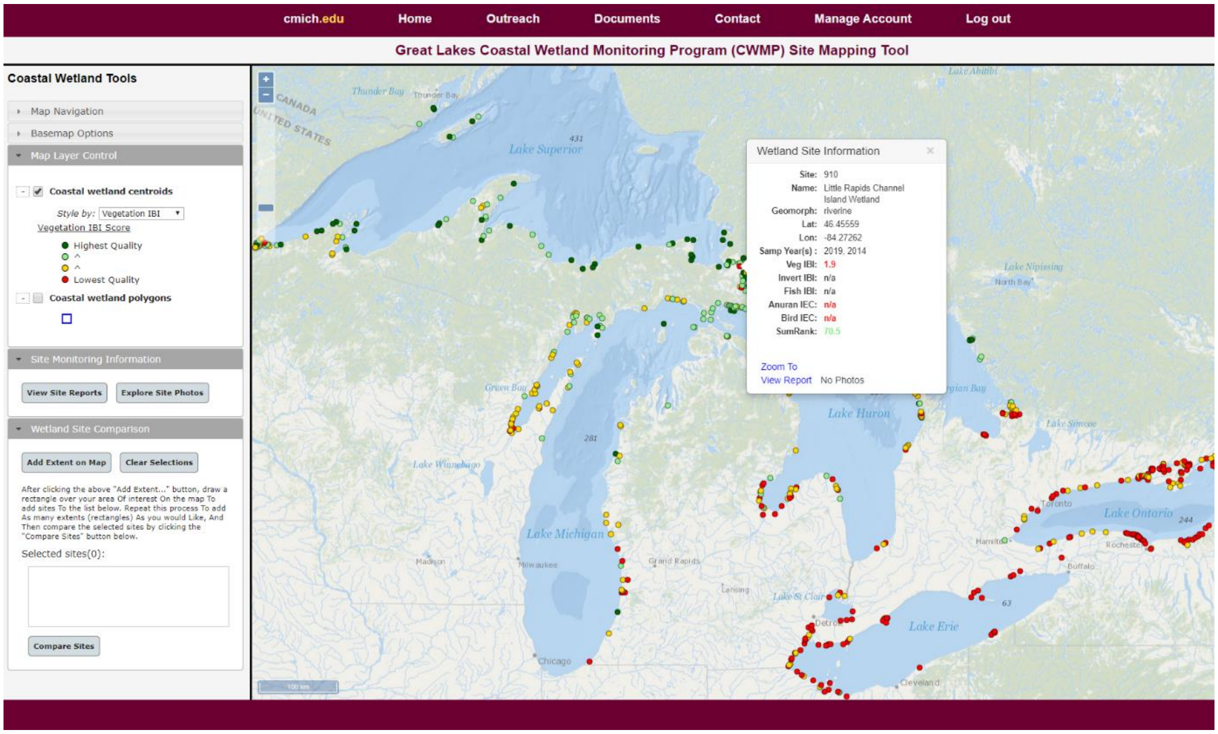

Figure 23. Coastal Wetland Mapping tool displaying the wetland macrophyte IBI scores ("Level 1").

Users with "Level 2" access to the website are provided with the same visualization options described above for the "Public" and "Level 1" access levels, but also have the capability of viewing a complete listing of species observed at individual wetland sites. Species lists can be generated by clicking on the "Species List" link provided at the bottom of the "pop-up" summary of site attributes (Figure 24), and the information can then be viewed and copied and pasted to another document, if desired.

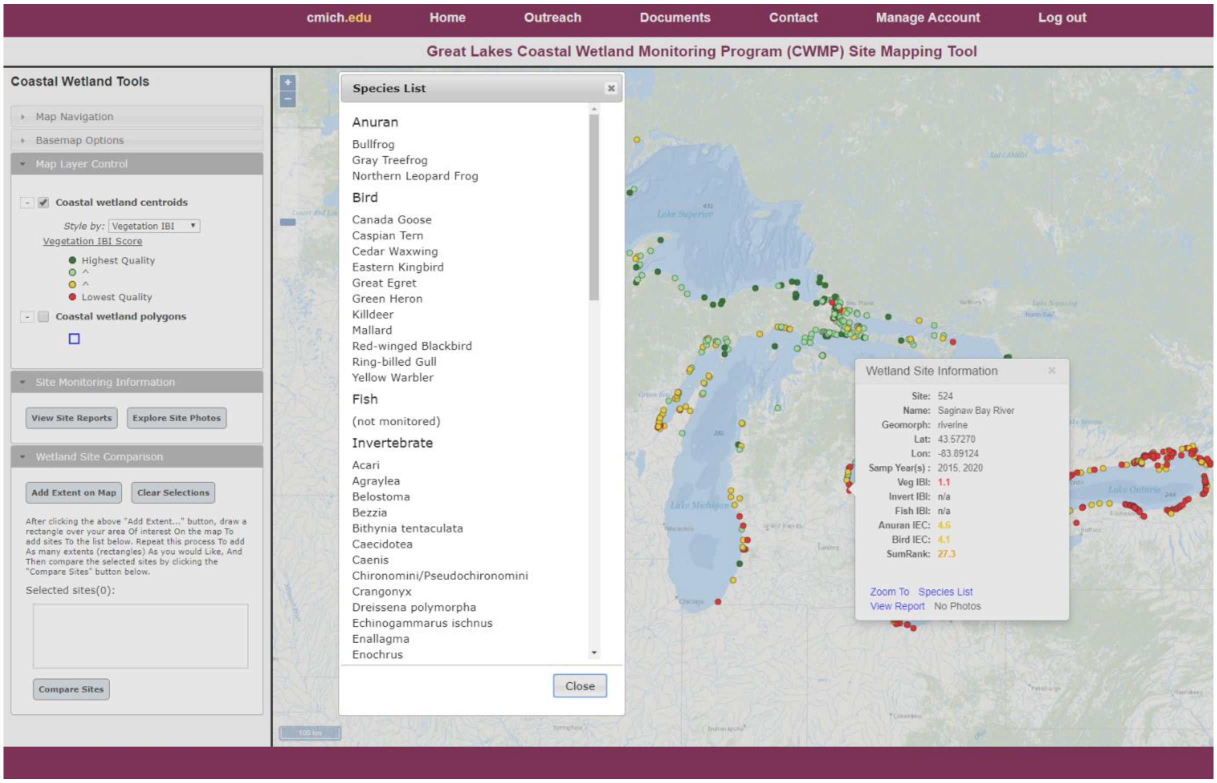

Figure 24. Coastal Wetland Mapping tool displaying the wetland macrophyte IBI scores along with species lists.

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.

In 2019, a one-hour documentary on the CLCWMP was release on PBS. The documentary airs across the U.S. "Linking Land and Lakes: Protecting the Great Lakes' Coastal Wetlands" chronicled the work of all 15 universities and government agencies documenting our scientists collecting data to help restore and protect these ecosystems. The WCMU production team traveled the entire Great Lakes basin over 18 months covering 5,000 miles in Michigan, Wisconsin, Indiana, Illinois, New York, Ohio, Pennsylvania, and Ontario, Canada. More than 40 coastal wetland scientists shared their expertise in the documentary. The documentary can be viewed at https://www.pbs.org/video/linking-land-and-lakes-hdo22u/ .

TEAM REPORTS

WESTERN REGIONAL TEAM: **Jerry Niemi and Annie Bracey (birds and anurans), Valerie Brady and Matthew Cooper (fish and macroinvertebrates), Nicholas Danz (aquatic vegetation), and Chris Filstrup (water quality)**

Field Training

Birds and Anurans
Training for calling anuran surveys was held on May 3, 2019 and bird crew training took place on May 16, 2019. 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) anuran 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. The primary crew was comprised of one long-time crew leader and two new crew members. As has been true the past several 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 has determined 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 Anurans
In 2019, a total of 51 sites were initially selected to be surveyed for birds and anurans 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 51 sites, 18 sites were rejected for bird surveys and 23 sites were rejected for anuran surveys either prior to visiting the wetland (web reject), following reconnaissance visits to each remaining site (visit reject), or road access did not permit the team to get close enough to the coastal wetland to accurately survey the site (could not access site), or because a specific benchmark site was not being surveyed (not sampling BM). All rejected sites for birds and anurans were due to accessibility issues. Most of these sites had been previously rejected in 2014 by bird and anuran 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 (anuran) surveys for safety reasons. Anuran crews were able to sample sites in northern Lake Huron beginning 03 May and bird surveys began 30 May. Sampling was completed by 08 July 2019 for birds and 16 July 2019 for anurans.

The 33 sites that were sampled by bird and anuran field crews stretched from the Duluth-Superior harbor area eastward along the south shore of Lake Superior to the eastern end of the Upper Peninsula of Michigan and into northeast Lake Huron. Our team surveyed eight benchmark sites in 2019, all of which were located in the St. Louis River estuary or the Duluth/Superior Harbor.

Fish, Macroinvertebrates, Vegetation and Water Quality
Fish/macroinvertebrate/water quality and vegetation crews visited 25 sites after accounting for over-capacity sites, special request benchmarks, and taking on sites for neighboring teams to help them out. Of the 25, 16 were on Lake Superior and 9 were on Lake Michigan. Seven sites were designated as benchmark sites, three were re-sample sites and two were pre-sample sites for 2020.

Water levels were still high in Lake Michigan compared to 6 years ago, and datasheet notes often referred to many zone types (e.g. lily and 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 large fyke nets again this year (e.g. wet meadow). The NRRI crew sampled 22 of the sites. The Northland College crew sampled an additional two sites on the Bayfield Peninsula of WI and one site in Pictured Rocks National Lakeshore.

Field sampling and preliminary interesting findings

Birds and Anurans
The sites sampled in 2019 were visited up to four times between 03 May and 16 July. At each site, three surveys were conducted for anurans and two surveys were completed for birds, one of which was conducted on the same evening as one of the anuran surveys. Sites surveyed for both anurans and birds were visited a total of four times, while sites surveyed only for birds were visited twice.

Anurans
In 2019, a total of nine species were recorded throughout our study sites for a total of 528 individuals and 238 full choruses counted (Table 16). The average number of individuals recorded per site visit was 6. The average number of species detected per wetland was 4.2 with a minimum of two and a maximum of seven. There were only two sites with seven species recorded, site 1068: Bark Bay Wetland, a barrier wetland on the south shore of Lake Superior near Herbster, WI and 1078: Nemadji River Wetland, a riverine wetland in Superior, WI.

Green frog at Pictured Rocks National Lakeshore

Spring peepers (*Pseudoacris crucifer*) were the most abundant species observed in all wetlands sampled, accounting for over a 37% of the anuran observations and the majority of full chorus observations. Bullfrogs (*Lithobates catesbeianus*), which are regarded as an invasive species in the Great Lakes region, were not observed this year.

Table 16. List of anurans recorded during 2019 surveys.

Species
American toad (*Anaxyrus americanus*)
Bullfrog (*Lithobates catesbeianus)*
Chorus frog (western/ boreal – *Pseudoacris triseriata & P. maculatas*)
Green frog (*Lithobates clamitans*)
Gray treefrog (*Hyla versicolor*)
Mink frog (*Lithobates septentrionalis*)
Northern leopard frog (*Lithobates pipiens*)
Spring peeper (*Pseudoacris crucifer*)
Wood frog (*Lithobates sylvatica*)

Birds

Birds were surveyed twice at each site between 30 May and 08 July. Surveys occurred once in the morning and once in the evening. A total of 75 identifiable species observations and 2,670 individual birds were recorded. The five most abundant species observed accounted for approximately 42% of all observations. These species, in order of decreasing abundance, were Red-winged Blackbird (*Agelaius phoeniceus*), Canada Goose (*Branta canadensis*), Song Sparrow (*Melospiza melodia*), Common Yellowthroat (*Geothlypis trichas*), and American Robin (*Turdus migratorius*).

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 2019 (Table 17). 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 five wetlands including two sites in Lake Superior, and three sites in northern Lake Huron. Least Bittern were observed at two sites in Lake Superior, one of which was in a site where restoration work has been done: Radio Tower Bay in the Duluth-Superior Harbor, MN. There were five sites where Virginia Rails were observed, two of which were in Lake Superior and three in northern Lake Huron. Sora rails were observed in eight wetlands; five sites in Lake Superior, one of which was in the restored site in Duluth-Superior harbor (Radio Tower Bay), and three sites in northern Lake Huron.

Common loon on nest

Eleven Bald eagles (*Haliaeetus leucocephalus*) were observed at 6 sites on Lake Superior, four of which were observed in the St. Louis River Estuary between Minnesota and Wisconsin, and two at restoration sites in the estuary (Dwights Point Wetland and Pokegama Bay Wetland #2). Additional species of interest include: Common Loon (*Gavia immer*), which were observed in 3 wetlands; Sandhill Crane (*Grus canadensis*) observed in 4 wetlands; and Common Tern (*Sterna hirundo*) observed at two wetlands within the St. Louis River Estuary.

Table 17. List of birds of special interest recorded during 2019 surveys.

Species
Sandhill Crane (*Grus canadensis*)
American Bittern (*Botaurus lentiginosus*)
Least Bittern (*Ixobrychus exilis*)
Virginia Rail (*Rallus limicola*)
Bald Eagle (*Haliaeetus leucocephalus*)
Common Loon (*Gavia immer*)
Sora Rail (*Porzana carolina*)
Great Blue Heron (*Ardea herodias*)
Belted Kingfisher (*Megaceryle alcyon*)
Common Tern (*Sterna hirundo*)

Birds of special concern were observed in 23 of the 33 wetland sites surveyed in 2019 (Table 17). The lack of observations of Black Tern (*Chlidonias niger*) and Forster's Tern (*Sterna forsteri*), and the two observation of Common Tern (*Sterna hirundo*), all species of concern throughout the Great Lakes, is of particular interest and concern.

As in 2016 – 2018, the bird and anuran teams included additional vegetation sampling at each of the point count locations in 2019. We used the Great Lakes Marsh Monitoring Program's sampling protocol, modified to fit our sampling design, 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

In 2019 we documented a fish species that we have not found before in our wetland sampling in western Lake Michigan. For several years we have collected only Longnose Gar in the northern half of Green Bay and only Longnose x Shortnose Gar hybrids in the southern half of Green Bay, even though there is no physical barrier separating the two populations. In the summer of 2019 the NRRI crew captured our first Shortnose Gar, found in the southern Green Bay area (Figure 25), which is also the first Shortnose Gar documented in the Coastal Wetland Monitoring Program database. Dr. John Lyons (retired Department of Natural Resources biologist, and present Curator of Fishes at the University of Wisconsin) confirmed the identification of this fish as Shortnose Gar, and added that while Longnose Gar x Shortnose Gar hybrids are much more common in Green Bay, Shortnose Gar are still present in very low abundance. The site where the Shortnose Gar was captured contained a lot of public litter that originates from a nearby highway overpass, so the fish community is largely comprised of species tolerant of degraded habitats with low oxygen and pollution, such as Common Carp, bullheads, and gar.

Figure 25. Shortnose Gar captured in southern Green Bay in 2019 by the NRRI field team, which is the first Shortnose Gar encountered in the Coastal Wetland Monitoring Program.

We were unable to sample 3 sites this year. These included a site in the mouth of the Fox River in Green Bay to which access was blocked by dredges removing PCB-contaminated sediments; a site which was drowned out and had no vegetation zones (vegetation present previously had been uprooted and washed away); and a site on the eastern Keeweenaw Peninsula of Michigan on Lake Superior that has been buried by stamp sands and no longer exists. Stamp sands are sand-sized particles generated as waste from an ore processing facility in Gay, Michigan, decades ago to remove iron ore. Millions of cubic yards of these waste sand-size particles were dumped into the coastal zone of the Keeweenaw and have been migrating south along the coast, burying coastal ecosystems to a depth of several feet in a band that extends a hundred meters or more from shore (Figure 26). Our crew sampled some remnant wetlands at the site in 2014, but nothing remained to sample this year. Unfortunately, we were unable to get good pictures on site, but Figure 26 shows the aerial view available on Google Earth. The band of

stamp sands can be clearly seen along the coast extending south from Gay, MI. More information can be found at this website:
http://www.geo.mtu.edu/KeweenawGeoheritage/Lake/Gay_Sands.html

Figure 26**.** Google Earth image from 2017 of stamp sands engulfing CWM site 1170. By 2019 the open water visible in this image had been buried by shifting stamp sands from Gay, MI.

The NRRI crew collected rusty crayfish only at one site in northern Lake Michigan (observed at 6% of fished sites). Crayfish are typical bycatch in fyke nets, and we encountered native crayfish species at 10 other locales (observed at 56% of fished sites). At the site in southern Green Bay where we captured the Shortnose Gar we also observed invasive zebra mussels attached to a floating log, and curly-leaf pondweed collected while making D-net sweeps for invertebrates.

Site 941 in Pictured Rocks National Lakeshore was designated a benchmark site in 2019 and was sampled by the Northland College crew. The wetland at this site is connected to Munising Bay, Lake Superior through a small culvert that becomes plugged with sediment on a regular basis. The National Park service is considering restoration work at this site to improve the natural connection between the wetland and the lake. The Northland crew sampled fish, macroinvertebrates, and water quality and found the wetland to be dominated by small non-piscivorous fishes with no large predatory fishes collected. Re-establishing the connection of this wetland to Lake Superior will likely open it to species like northern pike that could access the wetland for spawning or foraging. Additionally, re-establishing the connection of this wetland to Lake Superior may enhance the export of forage fish from the wetland to the Lake Superior nearshore.

Aquatic Macrophytes

In 2019 we again noted high water levels in wet meadow and emergent zones. One site (1040) was rejected because high water levels have severely flooded prior vegetation, which has subsequently been uprooted and washed away. We are noticing many alder thicket areas that border our wetlands have experienced substantial shrub die-backs associated with flooding. In many areas, these zones are transitioning back to wet meadow vegetation. For example in some cases *Carex lasiocarpa* is returning where it was not previously flourishing. In other areas, cattail monocultures and *Carex* sedge mats have been broken up, leading to open gaps and deeper watery depressions. In several sites in the St. Louis River estuary system, we have noticed expansion of cattail mats near the wetland edges where shrubs have died back. Wisconsin wetlands were found to have several rare plant taxa (Table 18) that have been reported to Wisconsin's Natural Heritage Inventory.

Table 18: Rare plants found in Great Lakes coastal wetlands in Wisconsin. This information was provided to the Wisconsin Department of Natural Resources Natural Heritage Inventory.

Plant Found	Wetland	Size of Population
Carex livida (*livid sedge*)	Lost Creek	One flowering individual and several scattered blue green blades
Carex livida (*livid sedge*)	Bark Bay	1-2 square meters of scattered individuals in transition between wet fen and shrubs
Drosera intermedia (*spoonleaf sundew*)	Lost Creek	Growing along a wet trail within the meadow
Drosera intermedia (*spoonleaf sundew*)	Bark Bay	Dense in areas with deeper water or more saturated sphagnum
Eriophorum russeolum (*russet cottongrass*)	Nemadji River	A large colony throughout the higher-quality meadow
Nuphar microphylla (*small yellow pond lily*)	Little Sand Bay	One flowering specimen in calm water
Salix planifolia (*tea-leaved willow*)	Nemadji River	A clump of shrubs on a small island in the meadow
Trichophorum alpinum (*alpine brush*)	Lost Creek	One small tussock on a hummock near sparse tamarack
Triglochin maritima (*seaside arrowgrass*)	Lost Creek	Two individuals scattered
Triglochin maritima (*seaside arrowgrass*)	Bark Bay	One individual in a slightly wetter area of the fen

Other Activities: The Great Lakes Coastal Wetland Monitoring Program led to a spin-off pilot project to investigate how well fyke net fish catches agree with fish eDNA collected from nearby benthic sediment. Making this linkage will allow us to investigate fish use of vegetation types that cannot be fished, such as wild rice beds in which standard fish sampling is considered too destructive of the rice plants. Dr. Valerie Brady and Dr. Chanlan Chun at the Natural Resources Research Institute will lead the eDNA pilot project. Matthew Cooper is working with Dr. Sarah Johnson at Northland College on a separate grant from the National Park Service to better understand the response of Apostle Island (Lake Superior) wetlands to future climate and water levels. Matthew Cooper is also leading the development of a Coastal Wetland Decision Support Tool that helps to communicate CWMP data to broad stakeholder groups (www.greatlakeswetlands.org/DST). The decision support tool is currently being expanded to the WI and MN shorelines of Lake Superior, which will complete development for the entire US shoreline of the Great Lakes.

Data Requests: We continue to provide fish, macroinvertebrate, aquatic vegetation, and water quality data and IBI scores to state agencies working to restore the St. Louis River and Green Bay Areas of Concern as well as the Bad River Band of the Lake Superior Tribe of Chippewa Indians Natural Resource Department (recently re-named the Mashkiiziibii Natural Resources Department).

2019 Sample Processing, Data Entry, and QC

The PIs conducted mid-season checks by visiting a few sites and verifying that proper protocol was being implemented. All data entry and QC for birds and anurans was completed (100%) during August-September 2019. 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 are being entered into the project database; difficult-to-identify macrophytes will be identified this fall and winter.

Metrics and Indicator Calculations

In Spring 2017, PI Danz used data from 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.

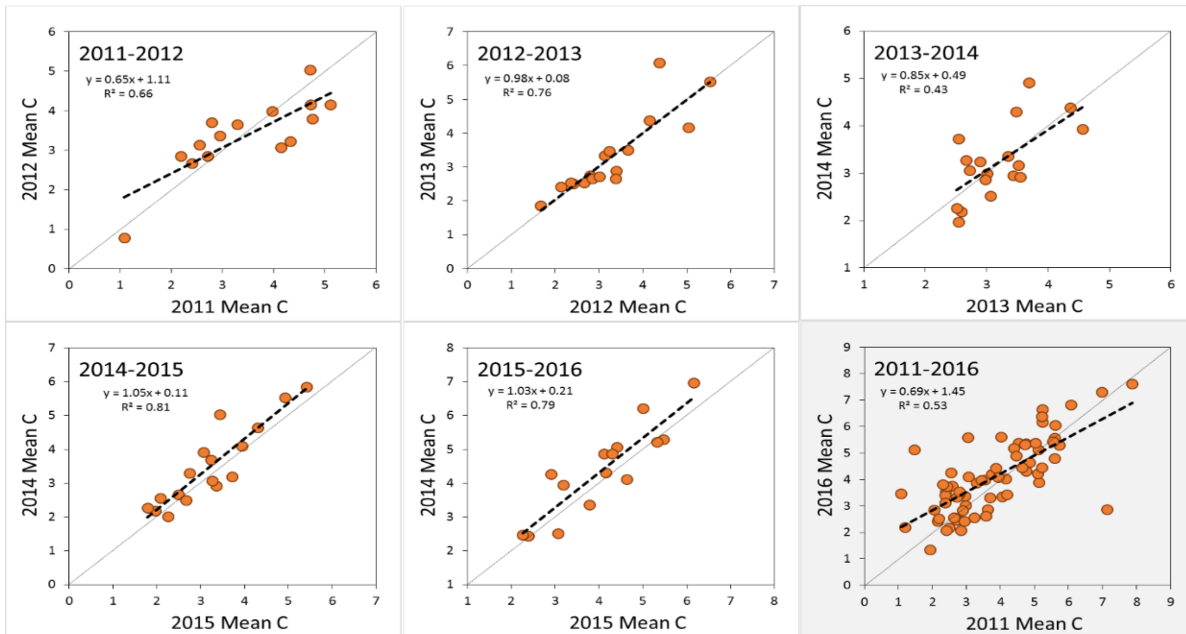

Figure 27. Patterns of change in Mean C for sites sampled in consecutive years and with a 5-y interval. Different subsets of sites were surveyed in each year-pair.

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 (Wisconsin DNR) 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.

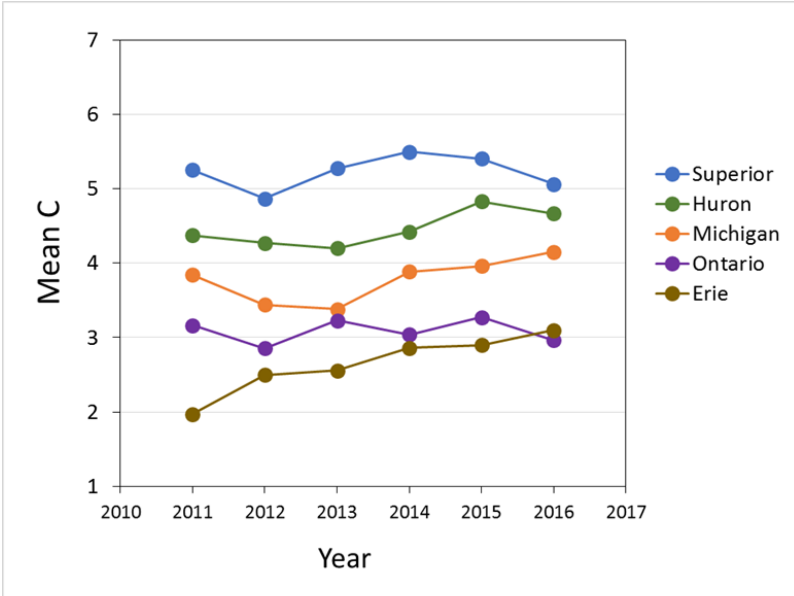

Figure 28. Average Mean C per year for individual Lakes. Measures of precision are not shown to preserve figure clarity.

Other Leveraged Benefits

Coordination and Potential Partnership with National Audubon: The CWM bird PIs continue to work with the National Audubon science team. The science team has continued to work with CWM bird data for the Great Lakes. As a result of their preliminary analyses, Nathaniel Miller of National Audubon Great Lakes and Kristin Hall of Audubon Minnesota have identified the St. Louis River Estuary as a critical area in which they would like to begin a more focused collaboration. A meeting and field site review was held in late May, 2018 in Duluth. This meeting involved the Executive Director of Audubon Great Lakes and the Vice-President of the Upper Mississippi Flyway as well as representatives of the Minnesota Land Trust. National Audubon and the Minnesota Land Trust interests focus on the identification of key areas for conservation in the St. Louis River system as well as developing a way for volunteer, citizen scientists to participate in monitoring, research, and conservation.

Modeling of Bird Species of Conservation Concern in the Great Lakes Coastal Region: Lisa Elliott completed her PhD in the Conservation Sciences Ph.D. program at the University of Minnesota, Twin Cities. Niemi is co-advising Elliott along with Dr. Douglas Johnson, a wildlife statistician. Her research used Coastal Wetland Monitoring Program bird data and data from inland lakes and the Prairie Pothole region to model the distribution and abundance of marsh-obligate species of concern in the Great Lakes region to identify habitat associations related to site occupancy.

To better understand the distribution patterns and habitat associations of rare and declining wetland birds in the Great Lakes basin, she developed six single-species, multiscale occupancy models using seven years (2011-2017) of bird survey data from the Great Lakes Coastal Wetland Monitoring Program and remotely sensed landscape data. These hierarchical models account for separate processes of occurrence and, given occurrence, detection, while also accounting for the CWMP's nested spatial and temporal avian monitoring approach. Results indicate that the probability of detection, given occupancy, for Least Bittern (*Ixobrychus exilis*) and American Bittern (*Botaurus lentiginosus*), Pied-billed Grebe (*Podilymbus podiceps*), Virginia Rail (*Rallus limicola*), Sora (*Porzana carolina*), and Common Gallinule (*Gallinula galeata*) ranges from 80-98% over multiple detection periods and multiple visits. This finding suggests that the CWMP protocol of broadcast calls and repeated visits within and between seasons is successful at locating these species. However, these species are very rare and thus were infrequently encountered during the surveys, with each focal species found on <20% of wetlands.

The model-estimated percent of wetlands occupied in at least one year of the survey (out of a total of 641 wetlands surveyed from 2011-2017) varied in increasing order as follows: Common Gallinule (37%), Sora (37%), American Bittern (45%), Pied-billed Grebe (51%), Least Bittern (58%), and Virginia Rail (71%). However, these models resulted in very wide credible intervals, suggested little confidence in the occupancy predictions and habitat associations indicated by the models. The high degree of uncertainty could be due to 1) the focal species being eurytopic (able to tolerate a wide range of habitat characteristics and thus unselective), 2) the focal species responding to as-yet unmeasured sources of variation in the highly dynamic coastal wetlands systems, or 3) the effective sample sizes of these rare species being too small to appropriately model as many levels of spatial and temporal nestedness as are necessitated by the sampling protocol. If the species are eurytopic, maintaining and restoring any existing coastal wetlands will be a useful conservation action. Additional years of data collection will facilitate larger effective sample sizes, to rule out the latter.

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

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

CENTRAL MICHIGAN UNIVERSITY

Fish/Invertebrate/Water Quality Crew

Central Basin training was led by CMU this year at site 515 on June 19th and 20th. Crews from LSSU, UND, and GVSU attended. The training was difficult this year as water levels were extremely high. Proper zone identification, as well as restrictions on fish or macroinvertebrate sampling, were discussed in detail. The training covered protocols for macroinvertebrate and water quality sampling but fish sampling was not possible due to depth restrictions. Shortly after, PIs determined that new protocols would need to be enacted to sample during these high water conditions. Crews individually practiced using these new “deep water” protocols and CMU resampled the training site the following week.

Field sampling began on June 19th, 2019. Central Michigan University was assigned 23 sites including 7 benchmarks. Benchmark 7075 was added upon request this year by USGS in alignment with work being conducted in the area. Sites 616 and 619 in the Les Cheneaux Islands were also sampled out of order this year to ensure overlap with an outside project. Of the 23 sites assigned to be sampled, site 839 was later traded to LSSU and three sites were visit rejected. Site 592, Cheboygan Area Wetland #4, was rejected on site as there was little to no vegetation present. The polygon encompassed a small, rocky area with large willow trees along the majority of the shoreline. This site likely has a wetland area less than 4 hectares in lower water level conditions. Site 641, Prentiss Bay Area Wetland, was rejected on site as there was little to no wetland vegetation. This site primarily consists of a rocky shoreline and substrate with a man-made beach. The site has been rejected in previous years for the lack of wetland vegetation. Site 757 was rejected due to a lack of access. There were no roads near the site and the closest boat launch was well over 15 miles away. In total, 49 zones were sampled for water quality, 34 zones were sampled for invertebrates and 32 zones were sampled for fish (Table 1).

Water quality, macroinvertebrate, and fish data and samples (along with other associated measurements) were collected for all vegetation zones identified that were within the sampleable water depths. Water quality was sampled in several zones that were too deep for fish and macroinvertebrate sampling. With the new “deep water” protocols, there was an adjustment period as crews determined what depths macroinvertebrates could safely and effectively be sampled. For many vegetation zones, water quality and fish were sampled but macroinvertebrates were not.

The following recommendations were made for sampling macroinvertebrates in depths greater than 1 m:

1. Extend dip net handles to increase the maximum collection depth. CMU crews extended dip nets with thick dowels attached to the handles using multiple hose clamps.

2. Extra caution should be used with extended dip nets to ensure safety of all crew members on the boat.

3. Move the boat around frequently to new un-sampled areas.

4. Crews have been advised not to try to sample macroinvertebrates deeper than 1.5 m due to lack of effectiveness and inability to properly reach bottom substrate.

With the new "deep water" protocols, fish were collected at all sites except for 755, where the water was too shallow and the substrate too rocky. Many of the sites sampled had vegetation zones with dead or dying trees and shrubs mixed throughout, making it difficult or impossible to set fyke nets (Figure 29).

Figure 29. Standing dead trees and shrubs pervasive throughout a *Typha* zone at site 616 making it difficult to set nets in this zone.

This typically occurred in wet meadow or Typha zones. In these cases, fish sampling did not occur. Due to high water levels, fyke nets were often set from the boat using the motor to back the boat through the vegetation zone. In many cases, poles were used to manually push the boat through vegetation as it was too thick to effectively use a motor. This also reduced damage to vegetation. Crew members set nets from the bow as the boat was backed through the vegetation and would pull the net from the bow the following day. This process often took a significant amount of time due to thick vegetation or windy conditions that made it difficult to properly maneuver the boat. A combination of 8 foot long posts and anchor/floats were used to set nets throughout the field season. Gear was selected based on how thick the vegetation was and wind conditions.

The following recommendations were made for sampling macroinvertebrates in depths greater than 1 m:

1. Keep extra conduit or poles handy for maneuvering the boat in thick vegetation and for helping hold position in windy conditions.
2. Use a combination of anchors/floats and posts:
    - For thin or sparsely vegetated zones (all bulrush, floating leaf, SAV, most PSP, thinner Typha areas) nets can be set with anchors and float lines. Prep the net by having it in the correct position with at least some of the anchors and float attached prior to approaching the area.
    - For thickly vegetated zones (most Typha and Phragmites), use the motor to get the boat as close as possible to where the lead needs to be set. Setting with conduit or other posts with flagging tape makes finding the wings easaier in dense vegetation. Pick-up will be quicker due to visibility of flagging and ease of pulling conduit vs. anchors.
    - Mark everything for ease of pulling the next day AND for others to avoid gear. Flagging tape on conduit and/or extra bright buoys/floats. With deeper water and more sparse vegetation there is more likely to be private watercraft near nets.

At a subset of sites, a crew member with a dive skin attempted to assist with sampling of deep areas. It was determined that this would add a new set of safety conditions and often was not helpful. We do not suggest employing this option moving forward.

At several sites, large pieces of trash, tires and even lawn furniture were found (Figure 30), even in areas where trash has been rare in the past. It is possible that the combination of high water levels and intense storms throughout the season has contributed to the pollution found at sites.

Due to the logistics of dealing with high water levels, sampling was not completed until August 22, 2019. Fish/Invertebrate/WQ crew leaders then assisted vegetation crews with sampling in order to complete all sites in a timely manner. The lengthy field season, however, delayed the start of laboratory analyses and data entry. Fish unknowns are currently being confirmed in the laboratory. Macroinvertebrate identification is under way with approximately 20% of ID’s completed. Identification to appropriate levels and quality checks will be completed in early 2020. Water samples from LSSU have been received, while samples from UND have not.

Figure 30. Crews noticed an increase in large trash items including tarps nailed to wood (site 498), tires (site 493), pool floats, styrofoam and lawn furniture (site 629).

Vegetation Crew

PI Dr. Dennis Albert oversaw the Central Basin vegetation sampling crews which were led by Allison Kneisel (CMU staff). Crew member training began in mid-June of 2019. July 1st through 3rd all new crew members (and most returning crew members) attended a plant identification workshop led by Loyola researcher Shane Lishawa. At the end of the workshop, all crew members were certified in the identification of coastal wetland plants.

The Central Basin crews sampled 40 sites of the 52 that were assigned. Two sites were web rejected because no wetlands were seen in the aerial images, five sites were rejected for inability to safely access the site, three sites were not sampled because crews were over capacity, one site (592) was rejected because it was drowned out by high water levels.

Dr. Albert has identified all of the plant specimens collected during the field season. CMU crew members will be entering the data on to the CWMP database in the fall and winter of 2019 and datasheets will receive a final quality check by Dr. Albert.

Sampling crews noticed many impacts of high water levels including shortened and eroded vegetation zones (particularly wet meadows), the die-off or erosion of emergent species while submergent and floating species often increased in coverage, and the disruption of the typical pattern of zonation (Figure 31 and Figure 32). Often zonation consisted of a small section of

Figure 31. Photographs looking out at transect three in Epoufette Bay (Site 1586) taken in 2017 (left) and 2019 (right). Pictures were taken within 10 m of each other, note the water level change and change in vegetation density.

emergent or wet meadow vegetation behind a dead tree line separated from another larger patch of emergent vegetation by sections of open water or submerged vegetation. This loss of emergent vegetation was particularly characteristic of open lacustrine wetlands such as those along the north shore of Lake Huron or Lake Michigan. The thick organic material that forms in the wet meadow zone is particularly vulnerable to storm waves during extreme high water levels that occurred in 2019, resulting in intensive erosion of both the meadow vegetation and its roots, creating broad, deep mounds (wrack) of organic material along the shoreline. Additionally, at one site on there was a large floating mat of dead *Typha* that appeared to have separated from the main stands of *Typha* along the shoreline which may also be a result of increasing water levels. This same pattern was seen at research sites in Munuscong Bay along the St. Marys River.

Figure 32. A quadrat in Detroit River International Wildlife Refuge, Branchaeu Unit (Site 1915) where herbicide-treated *Phragmites australis* is being replaced by *Hydrocharis morsus-ranae*. Walking along the deep sections of the transect revealed many holes in the *Phragmites* mat.

Bird/Anuran Crew

We sampled anurans and birds in coastal wetlands on lakes bordering the Lower Peninsula of Michigan, the Upper Peninsula of Michigan near St. Ignace and Epoufette, and sites in western Lake Erie, Ohio during summer 2019. Three teams, each with two members, were used throughout the sampling season. Anuran training was completed by 8 March 2019 and bird training was completed by 16 May 2019 at CMU. Online testing was used for identification of anurans by sound and birds by sight and sound. All data collectors reached proficiency before sampling. Field crews consisted of undergraduate student technicians and graduate student field crew leaders.

We surveyed 46 wetland sites, of which 10 were benchmark sites. Of the original number of wetlands, we were assigned to sample (n = 51), we web rejected 3 sites, and 2 sites were not sampled because they could not be accessed. We sampled anurans during 24 April to 09 July 2019 and birds during 21 May to 09 July 2019. Wetlands were sampled three separate times for anurans and two separate times for birds. All 2019 anuran and bird survey data were uploaded and QC'd in the database.

UNIVERSITY OF NOTRE DAME

Fish/Invertebrate/Water Quality Crew

In March 2019, the University of Notre Dame (UND) was assigned eight wetland sites to assess for 2019. The team consisted of two experienced individuals, one new crew leader, and one undergraduate summer technician. All crew members will continue to be involved through the academic year to promote continuity.

In June 2019, the UND crew attended CMU's annual training in Saginaw Bay. Prior to and following training, the crew took inventory of equipment and supplies and reviewed CWMP protocols. Shortly after the training session, the UND PI (Gary Lamberti) accompanied the crew on a sampling trip to monitor field protocols but saw no need for corrections. Sampling started at the southernmost group of sites and moved northward (per the QAPP). All sites were sampled by the end of July 2019.

Of the eight assigned sites, five of the sites were riverine and three were lacustrine. Five of the sites were located in Lake Michigan, two sites were in Lake Huron (Saginaw Bay), and one site was in Lake St. Clair. Due to high water levels in the Great Lakes, the majority of sites had markedly higher water levels than recorded in the past, and the crew often had trouble finding suitable places to set fyke nets. Of the fourteen vegetation zones sampled, only six were fishable. Efforts to anchor nets in deep (>1 m) water with various gears were unsuccessful.

Ecosystem disturbances observed included broadly scattered anthropogenic debris, including plastic bottles, golf balls, metal scraps, and fishing material. On a more positive note, we observed a wide variety of wildlife, including swans, grebes, ducks, blackbirds, numerous great blue herons, various species of turtles, and northern water snakes (*Nerodia sipedon*). People observing the crew often seemed curious. They responded positively when the crew explained that they were sampling wetlands to determine their health, and to keep them in good shape for fish and wildlife to utilize. The most common questions were regarding which fish were caught and where. Overall, there was a general tone of enthusiasm about the project, especially from anglers.

Presently, all habitat, fish, and field water quality data have been entered into the CWMP database and QC'd by a second person. Macroinvertebrate sample processing and identification is well underway, with roughly sixty percent identified to family. By the annual meeting in February, all invertebrates will be identified. To assist with identification, our IDer (Klepinger) is currently taking an aquatic entomology course at Notre Dame taught by Professor Ronald Hellenthal, a renowned entomologist. Transportation of chlorophyll-a samples from Central Basin collaborators to Notre Dame is being coordinated, and sample processing is expected to be finished by January of 2020.

GRAND VALLEY STATE UNIVERSITY

Fish/Invertebrate/Water Quality Crew

Two new crew members and one returning crew member received hands-on training on the field sampling protocols on 18 June 2019 at the training led by CMU in Bay City, MI. Further training on field sampling protocols was led by Travis Ellens (crew leader) and Dr. Carl Ruetz on 25-26 June 2019 in Mouillee Marsh (Monroe and Wayne County, MI) and Trenton Channel Wetland (Wayne County).

The crew were able to sample all 8 wetland sites that were assigned. All sampling was conducted during June-August 2019. The crew sampled 19 plant zones for macroinvertebrates and water quality; however, only a subset of those zones were sampleable for fish, mostly due to high water levels.

All field work for 2019 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 QC for macroinvertebrate and lab water quality samples. Macroinvertebrate identification will begin in October and all macroinvertebrate data should be entered and checked by early spring 2020. Samples for SRP, TP, NH_3, NO_3, Cl and chl-a have been sent out for processing, and the observations will be entered and checked once completed.

In addition to field work, the Ruetz lab continued to work 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 American Midland Naturalist; it is currently under review.

Overall, the 2019 sampling season was successful. The sampling period (June-August) coincided with maturation of plants, which made for easier identification of plant zones. On average, it took the crew (3-4 people) about 10-12 hours in total (i.e., for the entire crew) to finish an entire site (collecting fish and macroinvertebrates and processing water quality). All equipment (i.e., truck, boat, YSI sonde) worked without issue throughout the sampling season. The main challenge was high water levels making wading difficult in many of the plant zones. A number of plant zones were sampled for macroinvertebrates and water quality from the boat due to water depths greater than 1.25 m. Occasionally fyke nets were set in deep water using two large floats tied to the last ring to ensure the top of the cod end was above the water surface to prevent turtles and other air-breathing vertebrates from drowning. AWRI purchased a new, larger jon boat in fall 2018, and this boat greatly improved our ability to sample wetland sites that require long boat rides in the open water of Lake Michigan and Lake Erie. Additionally, this 24 foot jon boat has more deck space to work, which proved to be invaluable when the high water levels did not permit the crew to wade in some of the wetland plant zones.

LAKE SUPERIOR STATE UNIVERSITY

Fish/Invertebrate/Water Quality Crew

Crew members were trained and certified in sampling protocols in June by Ashley Moerke (LSSU PI), and then the crew attended the training session offered by CMU in Saginaw Bay in June. From late June to August, the LSSU crew visited 11 sites, 8 in US waters and 2 in Canadian water, to determine if they met the sampling criteria and if they were accessible. Five sites were rejected upon visiting, primarily due to no sampleable wetland vegetation zones present. Often water levels were so high that the shoreline vegetation (e.g., tag alder) was inundated. The remaining six sites were sampled at least for water quality, macroinvertebrates, and other associated measurements for all vegetation zones identified and that were within the sampleable water depths. In numerous cases, water depths at vegetation zones exceeded 1 m, but every effort was made to sample those zones when possible.

Water from each site was separated; some were filtered, some frozen, and some analyzed for alkalinity and color in the lab. Water samples were mailed to Central Michigan University the week of 9/23/19 for dissolved nutrient analyses and filters were mailed to the University of Notre Dame for chlorophyll a analysis on 9/24/19. All 2019 data, except for lab data and macroinvertebrate identification data, have been entered into the on-line database and were checked by a second reader. Macroinvertebrate data identification will begin in late November and will likely be completed by March 2020.

Water levels were extremely high again 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 sampled using the adjusted protocol for deep water sampling that was distributed to field crews this summer.

In addition to the sites assigned, an undergraduate student and wetlands crew member, Derek Hartline, sampled five additional sites. These were all sites and vegetation zones that had been sampled in previous low water years, so data collected this year will be used to compare fish communities in low and high water years. A second undergraduate student, Dylan Loop, will be using the St. Marys River wetland fish data to look at the use of wetlands by young-of-year fishes throughout the river.

Site 820 was added this year as requested by the Bay Mills Indian Community who are working on a project trying to understand wetland health on their reservation, including inland and coastal wetlands. The tribe is adopting GLCWM protocols to continue assessing the health of their waters as well as determine their potential for wild rice restoration.

Eastern U.S. Regional Team: Douglas Wilcox and Katie Amatangelo (Lead), Chris Norment (Birds and Anurans), James Haynes (Fish and Macroinvertebrates)

Site selection

The College at Brockport worked with Environment and Climate Change Canada and Bird Studies Canada to redistribute site assignments to match crew capacities relative to the spatial distribution of sites. Nine Environment and Climate Change Canada sites from the north shore of Lake Ontario were reassigned to Brockport for fish, aquatic macroinvertebrates, water quality, and vegetation sampling. Three wetlands, all located in the Rochester Embayment Area of Concern, received benchmark tags for Brockport to collect data for ongoing restoration projects. In all, The College at Brockport was assigned 23 sites for fish, aquatic macroinvertebrate, water quality, and vegetation sampling, and 21 for bird and anuran sampling.

Training

Only one of Brockport's 2019 crew members was a returning member from the 2018 field season, with her area of expertise in bird and anuran sampling. The new crew members received training from Gregory Lawrence, Dr. Douglas A. Wilcox, Dr. Kathryn Amatangelo, Dr. Michael Chislock, Dr. James Haynes, Dr. Courtney McDaniel, Dr. Christopher Norment, and Dr. Rachel Schultz from The College at Brockport, as well as former crew chief Brad Mudrzynski, Dr. Valerie Brady from University of Minnesota Duluth and Dr. Joseph Gathman from University of Wisconsin-River Falls. The new crew members all passed training requirements. Additionally, all crew members passed mid-season QA checks performed by Dr. Douglas Wilcox and Dr. Christopher Norment.

Sampling

The College at Brockport bird and anuran sampling crew successfully sampled 21 of the 21 sites assigned to them between 1 May and 10 July 2018. The summer fish, aquatic macroinvertebrate, water quality, and vegetation crews were assigned 23 sites. In total, the fish crew sampled 15 of 23 sites, the invertebrate and water quality crew sampled 16 of 23 sites, and the plant crew sampled 21 of 23 sites. Two sites were not sampled due to lack of access. Four sites were only sampled for vegetation due to lack of boat access for the other crews. Most of these sites would typically be accessible, but high lake levels made access under bridges and off roadsides impossible this year. One site was only sampled by the invertebrate/water quality and vegetation crews due to lack of access to appropriate zones for the fish crew. Although most sites were sampled, it was difficult to find shallow enough zones to sample. In the past, crews often sampled many submerged aquatic vegetation (SAV) zones at sites, but all of these were too deep this year to safely sample under protocols.

Figure 33. College at Brockport crew picking invertebrates.

Laboratory work

Laboratory analyses of water samples at The College at Brockport are finished, while aquatic macroinvertebrate identification has just begun and is approximately 10% complete and will be complete by March.

Data entry and QC

Bird and anuran data are 100% entered, and all bird and anuran data have received quality control checks. Vegetation data entry is 100% complete and all have received quality control checks. Data entry for 100% of fish, field-level water quality, and field-level aquatic macroinvertebrates has been completed and all have received quality control checks. Data entry for aquatic macroinvertebrate laboratory identifications has not started because laboratory identification has just begun.

Collaborations with partner agencies and organizations

The College at Brockport continued to work closely with restoration partners to collect more pre- and post-restoration data at select wetlands near Rochester, NY. Braddock Bay (7052) was designated a benchmark site; the data will be used to supplement U.S. Environmental Protection Agency-funded post-restoration data collection for the New York State Department of Environmental Conservation and U.S. Army Corps of Engineers (USACE) at the site following a USACE restoration project completed there in summer 2018.

Cranberry Pond (50) was also sampled as a benchmark site; data from this site will be used to supplement pre-restoration monitoring for a National Audubon Society-led restoration project at the site. Sampling revealed a rare coastal fen community. Nearby Buttonwood Creek (7026) was designated a benchmark site to continue assessment of the wetland following fen and emergent wetland restoration activities and as a reference for the restoration project at Cranberry Pond.

Finally, The College at Brockport continued to communicate invasive species presence to local authorities during the 2019 Coastal Wetland Monitoring Project season. 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

Regional Invasive Species Management (FL-PRISM) and the New York State Department of Environmental Conservation about infestations the crew found in Braddock Bay and Long Pond (29). The New York Department of Environmental Conservation, the agency that manages these wetlands, worked with FL-PRISM and Genesee Valley Audubon Society during the summer to document and eradicate the infestations reported by the Great Lakes Coastal Wetlands Monitoring Project crew. Further, crews notified these agencies of other invasive plant species, such as *Hydrocharis morsus-ranae* (European frogbit) and *Phragmites australis*.

Crews found tubenose goby (*Proterorhinus semilunaris*), an emerging invasive species, at Reeds Bay 1 (5806) in Canada and reported it to Environment and Climate Change Canada.

<u>Flora and fauna highlights and other notes</u>

Although water levels on lakes Ontario and Erie were at record highs, this was a good year for focal bird species. American Bittern (*Botaurus lentiginosus*), a species of special concern in New York State, Least Bittern (*Ixobrychus exilis*), a threatened species in New York State, and Virginia Rail (*Rallus limicola*) were detected at multiple sites. Common Gallinule (*Gallinula galeata*) was detected at multiple sites and continues to become more prevalent in coastal wetlands in this region. Invasive Mute Swans (*Cygnus olor*) were detected at a few sites, and large groups were noted at Braddock Bay (7052).

The vegetation crew found some interesting plants, including wild rice (*Zizania palustris*) at a few sites (Hay Bay Marsh 3 (5402) on Lake Ontario and Long Pond Wetland #1 (1841) on Lake Erie). Further, they sampled two sites with coastal fens: Buttonwood Creek (7026) and Cranberry Pond (50), and found sundew (*Drosera rotundifolia*) and other unique peatland species.

The fish crew had a banner year for turtles, catching four species including painted (*Chrysemys picta*), snapping (*Chelydra serpentina*), map (*Graptemys geographica*), and many musk turtles (*Sternotherus odoratus*). Other highlights included longnose gar (*Lepisosteus osseus*) at East Bay Marsh 4 (5256) and spotted gar (*Lepisosteus oculatus*) at Long Pond Wetland #1 (1841).

Lake Ontario water levels were at record highs this year and many zones were too deep to fish safely under sampling protocols. Multiple sites were inaccessible by boat because lake levels were up to the bottoms of bridges or overtopped access roads. Many boat launches were flooded and the barrier beaches at Black Creek Wetland (79) and Blind Sodus Bay (82) were mostly underwater, greatly increasing connectivity to the lake.

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

Field Training

Birds and Anurans
All crew members who collected bird and frog data this year had been with the project for multiple previous seasons. All of these individuals received refresher training on field protocols from PI Doug Tozer 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 anuran 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. All people collecting data had previously shown comprehension of the topics through written and practical test, and all had successfully completed the online anuran and bird identification tests. No problems were identified during the course of the field season.

Fishes, Macroinvertebrates, and Water Quality
Canadian Wildlife Service (CWS) field crew members who worked with fishes, macro-invertebrates, vegetation and water quality sampling were trained by Ian Smith and Hayley Rogers in the Toronto Region during June and July 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. A mid field-season check was conducted in July. No problems were identified.

The CWS crew leader in 2019 was Ian Smith. In June, he gave refresher training to the water quality, invertebrate, and fish sampling crew. Hayley Rogers trained new crew members on the vegetation sampling protocol.

Continuing University of Windsor field crew members who worked with fishes, macro-invertebrates, and water quality sampling had worked on the project since 2017, 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.

University of Windsor crew leaders in 2019 were Stephanie Johnson (three prior years of experience on the project), and co-PI Joseph Gathman. Previous crew members Jessica Robson and Nathan Tuck received certification for identifying common fishes and Species at Risk through the Royal Ontario Museum's course in fish identification. 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. All field sampling was directly supervised by Joseph Gathman or Stephanie Johnson.

In June, Joseph Gathman traveled to Brockport, NY, to assist project coordinator Valerie Brady in a training/refresher session with the crews from CWS and The College at Brockport. This allowed crews to ensure that all, including University of Windsor, were implementing sampling protocols in the same way.

Vegetation
Vegetation surveys were conducted by expert botanist Carla Huebert (vegetation field lead since 2013). She was provided with update e-mails from the project coordinators regarding the spread of existing invasive species, and the possibility of new invasive species appearing in Great Lakes wetlands. For the CWS crew, Hayley Rogers led the vegetation sampling and identification and was assisted by Albert Garofalo and Sara Burilo. 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 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

Birds and Anurans
Bird and anuran field crews evaluated 68 sites that had been selected and ordered for potential sampling in 2019 (37 on Lake Ontario, 20 on Lake Huron, and 11 on Lake Erie). Of these, 13 were not surveyed because access was unobtainable. Fifty-five sites were visited (each on 5 occasions) and sampled for anurans and birds.

Fishes, Macroinvertebrates, Water Quality, and Wetland Vegetation
The CWS crew visited and evaluated 11 locations along the north shore of Lake Ontario. Four sites were not sampled for fishes due to high water levels that exceeded the feasibility of the deep water fishing procedure and, in most cases, vegetation zones that did not meet the required minimum patch size.

The University of Windsor crew was initially assigned 36 sites on lakes Erie and Huron or the connecting channels. Of these, two were rejected based on remote (Google Earth) examination of the sites. Three other sites were not visited by crews because of inability to acquire access permits. Two other sites were visited but not sampled due to safety or denial of access on private property. Thus, 29 sites were visited by fish/invertebrate/vegetation crews and two of these were not sampled. Therefore, the combined efforts of CWS and Windsor crews resulted in a total of 40 sites sampled; 11 on Lake Ontario, 14 on Lake Erie (5 of which were in Ohio and 9 in Ontario), and 15 on the Ontario shore of Lake Huron.

Vegetation was surveyed, and invertebrates and water samples were collected at all 40 sites that were accessible. Five sites were not fished because they lacked suitable habitat or were too deep for safe net deployment.

Benchmark sites
Three benchmark sites were identified for sampling in 2019 (Point Pelee Marsh 2 in Point Pelee National Park; Mentor Marsh in Ohio, in cooperation with the Cleveland Museum of Natural History; and Howard Marsh, adjacent to Mentor Marsh). One additional site (Crane Creek in the Ottawa National Wildlife Refuge) was retained as a benchmark site for bird and anuran monitoring. This site was an ongoing area of interest to the USGS, who had studied it for the previous 7 years (K. Kowalski, USGS, Ann Arbor, MI, *pers. Comm.*). However, their research has concluded; consequently, this site was not sampled.

Point Pelee Marsh 2 wetland was sampled at the request of Parks Canada who are instituting a 5-year restoration project to increase the amount of open water area. Over the past 20 years *Typha* coverage has expanded in many areas, reducing the extent of fish habitat. The marshes are one of a handful of Canadian sites harboring several fish Species-at-Risk, including Spotted Gar, Warmouth, Pugnose Shiners and Spotted Suckers. Mentor Marsh has been a site of active wetland restoration and common reed (*Phragmites*) control efforts for several years. This marsh will be sampled periodically in the future to track the ongoing changes. The Howard Marsh site was sampled in response to a request by NOAA.

Data Entry and Quality Assurance

Most bird and anuran data have been entered and quality assured; some data entry remains and will be completed later this fall. All fish, vegetation, and field-collected water quality data have been compiled, entered into the database, and quality assured. Many of the 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 most sites, but are waiting for records from 8 locations sampled at the end of the summer.

Significant Observations:

Birds and Anurans:
Of note were 95 point occurrences of 9 Ontario bird species at risk (Table 19) based on information currently in the database; totals for some of the species will increase after remaining bird data entry is completed later this fall.

Also of note were 10 occurrences of Chorus Frog, which is listed as threatened in Canada (vs. 11 occurrences in 2018). As with the bird occurrences reported above, this total may increase once anuran data entry is complete.

Table 19. Ontario bird species at risk observed in 2018 and 2019 sampling.

		# Occurrences	
Species	**ON-ESA/SARA Status***	**2018**	**2019****
Bald Eagle	special concern	5	13
Bank Swallow	threatened	19	15
Barn Swallow	threatened	34	38
Black Tern	special concern	0	9
Chimney Swift	threatened	4	4
Common Nighthawk	threatened	0	1
Eastern Meadowlark	threatened	0	1
Least Bittern	threatened	22	11
Bobolink	threatened	0	1
Total		**74**	**95**

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 2019 are preliminary due to incomplete data entry; occurrences for some species will increase once data entry is complete.

Fishes and Invertebrates

No non-native Round Gobies were found by the CWS team in Lake Ontario wetlands. Round Gobies were collected at 5 locations in Lake Huron, and at 3 Lake Erie sites. Tubenose Gobies were caught at in one Lake Huron wetland. Common Carp were captured at two wetlands on Lake Erie. Goldfish were also caught in several Lake Erie wetlands.

Other species of note observed during the 2019 field season included: Three Warmouth, two Spotted Gar and a Spotted Sucker caught in Lake Erie wetlands. The Spotted Gar was of particular note; it was found dead in a fyke net set in a *Phragmites* zone. The specimen was 82 cm in length, which, if confirmed would make it the largest specimen recorded in Canada. It has been sent to Fisheries & Oceans Canada for assessment and age determination. It will ultimately be housed in the Royal Ontario Museum collection.

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 were approved both by CWS and by the University of Windsor at the start of the sampling season. Reports to the permit granting agencies have been completed in draft form and will be sent to both regional administrators. Records of fishes caught will also be sent to local conservation groups in Ontario where appropriate.

As a complement to assessing possible biological condition implications of within-wetland variation in dissolved oxygen, the crew continued to sample zooplankton at selected wetlands. At each of 7 sites, we collected twelve 1-L aliquots of water, poured them through a plankton net (63-um mesh) and preserved the composite sample in ethanol for later investigation in the laboratory. Samples were collected at three water depths In each wetland – one in a dense emergent vegetation zone where DO concentrations were <1.0 mg/L, one in deeper water at the approximate emergent-submergent vegetation zone boundary, and one in even deeper water where vegetation was sparse or absent.

Notes on Water Levels and their Influence on Sampling
Water levels in lakes Erie and Huron were historically high in 2019. Vegetation zones continued their multi-year trend of shifting their distributions up-slope in response to the higher levels and this influenced the ability to set fyke nets, and in some locations necessitated sampling macroinvertebrates from boats rather than by wading (see below). As noted in previous years, some sites continue to exhibit reductions in the extent of monospecific stands and a greater prevalence of species interspersion, including many open areas where little or no emergent vegetation is present. This appears to be a consequence of high water thinning out the wet-meadow vegetation while dense stands of cattail and other emergent vegetation persist further down-slope in deeper water and seem to be slow to expand up-slope into the previous meadow areas (also see below). The high water resulted in the emergent and wet meadow zones of sites having enough water to be fished but most sites were again limited to one or two fishable zones because most other vegetation zones were too deep to fish.

Lake Ontario water levels were extremely high in 2019, exceeding the record high set in 2017 and peaking in mid-June. This posed some challenges for the CWS fish and water quality crew. As instructed, the crew attempted to set fyke nets even when water depth exceeded 1 m. At one site water depth was close to 2 m in the SAV zone and setting the nets from the boat was not possible because the poles could not be secured. Other sites could not be fished due to lack of a suitable vegetation zone with large enough patches. *Typha* zones were the most commonly sampled vegetation type because the high water levels made these areas more accessible, less dense and deep enough to set nets.

Water Levels and Wetland Integrity in Lake Erie
Exceedingly high water levels in Lake Erie coupled with multiple storms and seiche events have threatened the integrity of several important protected wetland complexes along the north shore of west-central Lake Erie.

Prior to 2019, the Lake Pond marsh at Point Pelee was isolated from Lake Erie by a large, barrier beach that comprised the eastern shore of the Point. However, in fall 2018 the high Lake Erie water levels combined with sustained, strong northeast winds created seiche conditions that flooded the marsh. The cessation of winds resulted in a return flow that broke through the barrier beach separating the marsh from the lake. The breach has remained open for over a year.

Storms in 2019 have also completely eroded the barrier beach separating Hillman Marsh from the main lake. Furthermore, significant erosion has been reported along the shoreline separating Rondeau Bay from the north shore of Lake Erie proper. These three areas presently comprise almost the entire range of Spotted Gar and Warmouth, which are species-at-risk in Canada.

Monitoring Short-term Variation in Dissolved Oxygen and Water Levels
In 2019, we expanded a study begun last year to assess day-night variability in wetland dissolved oxygen, temperature and water levels to determine the influence that these variables may be having on samples of aquatic invertebrates and catches of fishes in fyke nets. We deployed one or more Onset Hobo dissolved oxygen (DO) loggers and light temperature recorders at the location of each fyke net in each wetland. In addition, we used Onset Hobo water level loggers at a single site within each wetland. Data were recorded every 15 minutes over a period of 18-24 h, depending on the duration of the fyke net sets. We anticipate that these loggers will provide us with information on daily DO maxima and minima, which will help define the environmental suitability of areas for mobile fishes and the likelihood of capturing them. Similarly, water level data will help us record seiche effects, which may influence both the abundance and composition of fish species in wetlands (e.g. Trebitz 2006).

University of Windsor M.Sc. candidate Nathan Tuck wrote and circulated an SOP in the spring, describing recommended deployment and recording procedures, and all teams were invited to collect water level data when they set fyke nets. In 2019, he monitored seiches in several Lake Erie wetlands over the course of the summer and detected marked movements of fishes into and out of protected systems that had a relatively narrow connection to the lake. He has recorded over 40 days of diel water level records in these wetlands.

University of Windsor Research Assistant Claire Shrimpton is receiving and compiling the basin-wide-scale water level data collected by participating CWM teams for 2019. We are still receiving records from the various CWM groups. In Canada, water level records were collected from 28 wetlands (4 on Lake Ontario and 24 from other locations). We have also received information on 10 wetlands collected by Central Michigan University crews. Colleagues from other CWM teams will also contribute data from late season sampling efforts

Reptiles
In Ontario, six turtle species occurring in the Great Lakes are listed as at risk under the *Species at Risk Act* (SARA): Spotted Turtle (*Clemmys guttata*) [Endangered]; Blanding's Turtle (*Emydoidea blandingii*) Great Lakes/St. Lawrence population; Spiny Softshell Turtle (*Apalone spinifera*) [Threatened]; and Eastern Musk Turtle (*Sternotherus odoratus*), Northern Map Turtle (*Graptemys geographica*) and Snapping Turtle (*Chelydra serpentina*) [Special Concern]. Under SARA, the Canadian Wildlife Service is responsible for developing a recovery strategy for endangered or threatened turtle species and a management plan for special concern turtle

species. Critical habitat is a component of recovery strategies and under SARA critical habitat is defined as ""the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species". The critical habitat may be based on the suitable habitat where turtles have been observed, including wetlands and watercourses (e.g., marshes, rivers, some lakes). Incidental observations from the Great Lakes Coastal Wetland Monitoring Program as well as other sources of turtle observations were used to identify many suitable habitat locations in Ontario as critical habitat. The data provided by CWMP were invaluable for critical habitat identification and continue to provide key information contributing to knowledge on abundance and distribution of all at risk turtle species.

Although the Windsor team has routinely reported inadvertent catches of turtles in fyke nets, this year for the first time we also recorded sightings observed during vegetation sampling. In all, the following individuals were observed by the CWS and University of Windsor teams:

Eastern Snapping Turtles (*Chelydra serpentina*) were recorded at 3 of 11 Lake Ontario wetlands. Northern Map Turtles (*Graptemys geographica*) were observed or caught in fyke nets at 5 Lake Erie wetland locations. On Lake Ontario, one Northern Map Turtle was caught. Painted Turtles (*Chrysemys picta*) were the most widespread species, with specimens caught at 16 locations. CWS reported this species at five wetlands on Lake Ontario. One Red-eared Slider (*Trachemys scripta elegans*) and one Spotted Turtle (*Clemmys gutata*) were observed. No Eastern Musk Turtles (*Sternotherus odoratus*) were observed in 2019, largely because they are most common in the Severn Sound region of Lake Huron which wasn't sampled in 2019.

This year, the UW vegetation crew also recorded all sightings of snakes during their surveys. The Northern Water Snake was the only species observed, found at one wetland in Lake Erie and two in Lake Huron.

Vegetation

Beginning in 2015, Great Lakes water levels have risen significantly after a prolonged period of low water. This has produced some significant 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. Beginning In 2016 and continuing to the present, delineating between vegetation zones has sometimes become a challenge because species that normally are found in monoculture are becoming increasingly 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.

With record high lake levels again in 2019, 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 fyke nets.

On Lake Ontario high water levels in 2019 brought noticeable changes in the meadow portion of vegetation transects. Although meadows were in some cases under 50 cm of water, grasses and forbs were identifiable through the clear water when CWS crews began sampling in late June. However, towards mid-July, grasses and forbs turned black and mushy. We noted that rhizomes from existing *Calamagrostis canadensis* and sedge species quickly spread into the now dead field meadow species stands and grew to emerge above the standing water. Juniper and ash saplings seemed to tolerate the temporary flooding much better than grasses such as Kentucky Blue Grass. One forb genus of note that seemed to do very well after the flooding and die off-of old field meadow grasses was *Lycopus*. These normally low-growing plants developed long stems with reduced leaves and grew to emerge above the high water level before putting out more typical leaves above the water line.

The rising Great Lakes water levels also continued to submerge and drown, or drastically reduce in size, many of the higher quality, diverse wet meadows in Lake Huron. The depths of many of these formerly dry or shallow meadows now exceed 30-100 cm of water; few meadow species are able to persist when the water levels rise and remain at high levels as they have in the past several years. During sampling this year we noted that a few select species seemed able to adapt to the sustained high water levels including Water Sedge (*Carex aquatilis*), Woollyfruit Sedge (*Carex lasiocarpa*), Sweet Gale (*Myrica gale*), Canada Blue-Joint (*Calamagrostis canadensis*), and Twig-Rush (*Cladium mariscoides*).These were the most common species found in the former meadow zones and were able to withstand and grow in water depths of up to 1 m or more.

Certainly, in lower water level years it was much easier to distinguish the boundaries between vegetation zones. in 2017, 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 formed the basis of Danielle Gunsch's M.Sc. thesis (University of Windsor 2019). Sampling along wet meadow transects extending from 30 cm to over 1 m in 10 pairs of wetlands, she found that the duration of hypoxia over the course of a day and associated habitat use by fishes broadly corresponded with water depth. Although she detected significant differences in macroinvertebrate community composition along depth transects, among-wetland variation in invertebrate composition was significantly greater than within-wetland variation. Her findings corroborate the validity of the CWM sampling design of collecting samples within vegetation zones of each wetland without needing to consider water depth or time of sampling during a day.

Range expansions of Invasive Plant Species

Nitellopsis obtusa

With new knowledge of the presence of Starry Stonewort (*Nitellopsis obtusa*) in the Lower Great Lakes, surveyors continue their efforts to locate and positively identify this non-native macroalga during wetland surveys. Canadian Wildlife Service and University of Windsor have previously identified abundant and widespread patches of *Nitellopsis* in Canadian portions of Lake St. Clair and the Detroit River.

Starry Stonewort (*Nitellopsis obtusa*) was found for the first time at a CWM-monitored Lake Erie site - Point Pelee Marsh (Site 5762). Prior to this year this invasive macroalgae had not been observed in Lake Erie, so it appears to have expanded its range into the lower Great Lakes. *Nitellopsis* was found in only one of three transects sampled, suggesting that it hasn't overtaken all of the shallower areas of this large wetland; but the sampling plots in which it was found covered the entire sampled quadrat area from substrate to surface, indicating that the patch is well established rather than being a recent colonist. Since this wetland was isolated from Lake Erie until recently (see above) and because no motorized watercraft are permitted in the marsh, this population likely came from an avian source.

Phragmites

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 through 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.

Invasive *Phragmites australis* has also begun to gain ground on Manitoulin Island where it had previously been absent in most of the wetlands sampled there. A dense stand, approximately 18 m x 16 m was found while sampling at the Lake Wolsley wetland in 2018. It will be informative to revisit to this site in a few years to monitor the stand's rate of expansion and to see if it begins to appear in other wetlands on the western side of the island.

In general, less *Phragmites* is present in Lake Ontario than Lake Erie. The regulation of Lake Ontario water levels likely contributes to this observation as regulation results in relatively stable water levels that expose shorelines less frequently than a naturally fluctuating system. *Phragmites* was found by the CWS crew at two Lake Ontario wetlands, both in the Greater Toronto Area (Humber River Marshes – 5441 and Four Mile Pond -5313). This is consistent with other surveys that have found greater amounts of *Phragmites* in more developed areas.

Invasive *Phragmites australis* was found for the first time this year at one northern Lake Huron site, Pumpkin Point (Site 5790). *Phragmites* was absent when this site was previously sampled in 2014. A sparse patch, approximately 15 x 10 m was observed in and around one of the sampled transects. Other emergent vegetation was observed interspersed among the *Phragmites* stems, but this site should be monitored regularly to see if this stand continues to expand.

We also observed first records of *Phragmites* at several other sites that had been sampled in previous years, including MacGregor Point Wetland 2 (Site 5585), Oliphant Wetland 5 (Site 5709), and Fishing Islands 5 (Site 5294), all located on or near the Bruce Peninsula. While Lake Huron's high water levels have not drowned out or reduced the *Phragmites* populations at these sites, the sizes of the beds at these locations have not increased, suggesting that the high water levels may have inhibited the stands' stem density and/or expansion into new areas beyond where it is presently established.

Trapa Natans

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 project 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.

Hydrocharis morsus-ranae

European Frogbit (*Hydrocharis morsus-ranae*) was found for the first time at any of our sampled northern Lake Huron sites, on St. Joseph Island. It was found at two sites on the island: Tenby Bay (Site 5975) and Everen's Point (Site 5276). At both sites it occurred nearest the shoreline, in sheltered, shallow water. While the Tenby Bay patch consisted of only three individual plants, the Everen's Point patch consisted of several hundred individual plants that followed the shoreline for at least 50 m - the length of shoreline that could be observed while sampling. There was also a large patch surrounding the small Everen's Point boat launch (off of MacGuire Drive), suggesting that a boat that had launched from this ramp was likely the source of introduction of Frogbit into this rather isolated wetland.

Collaborations

The CWS team engaged in discussion and/or site visits with the following individuals or groups during the 2019 field season: CWS continues to collaborate with the Mohawks of the Bay of Quinte, sampling Lower Salmon River (5562) for the first time in 2019 in addition to Airport Creek for a wetland resiliency project. Cootes Paradise (5161) and Hendrie Valley (5795) are conservation areas managed by the Royal Botanical Gardens which were accessed with permission. In cases where it was necessary to obtain permission to access the sites, we provided background on the project and the results of our findings for those sites.

Project Leverage Examples

The Canadian Wildlife Service – Ontario Region 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 combined bird and frog data from the CWM project with data from the Great Lakes Marsh Monitoring Program to look at the effect of *Phragmites* control on these taxa. The results have been summarized in a peer-reviewed manuscript that is currently in review entitled, "Control of invasive *Phragmites* increases breeding marsh birds but not frogs." The study looked at changes in 1) species richness, 2) total abundance, and 3) occurrence of 9 breeding marsh bird species and 8 breeding marsh frog species before and after control of invasive *Phragmites*. It took place between 2011 and 2018 throughout 3 Great Lakes coastal wetland complexes located on Lake Huron and Lake Erie in southern Ontario. The study found that at sample sites where invasive *Phragmites* was controlled, species richness of five breeding marsh bitterns and rails of conservation concern increased by 1.1 species, and that total abundance of these species combined increased significantly by 1.8 individuals. By contrast, the study observed no change in these responses at nearby sample sites where no *Phragmites* control occurred. The study found no change in occurrence of any frog species or species richness or crude calling frequency of all frog species combined in relation to control of *Phragmites*, although the study lacked the ability to detect subtle changes in abundance of frogs so more information would be helpful before firm conclusions can be made in relation to frogs and control of invasive *Phragmites* in the study system. The study shows that control of invasive *Phragmites* has a significant positive effect on breeding marsh bird species of conservation concern and suggests that continued effort to restore habitat for these species is warranted, particularly in areas where former breeding marsh bird biodiversity was high.

In 2019 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 2019 field season:

Greg Mayne (Environment and Climate Change Canada, Canadian Co-chair, Lake Huron Binational Partnership): We collaborated with Greg to obtain permission to sample Whiskey Harbour on Wiikwemikoong First Nations land on Manitoulin Island. Both the tribe and Environment and Climate Change Canada have targeted this wetland as part of their coastal-wetland resiliency study. However, ultimately we were unable to coordinate sampling with them.

In 2018, we were advised of a new wetland restoration initiative to decommission a local marina and restore a wetland at the mouth of Sturgeon Creek in western Lake Erie by the Region Conservation Authority and the Caldwell First Nation. The restoration activity was undertaken in spring 2018. We designated this site as a benchmark and were able to sample vegetation upstream of the area in that year. Sampling was conducted for fishes, vegetation, invertebrates and water quality in 2019.

Mentor Marsh, on the shore of Lake Erie near Mentor, OH, is administered by the Cleveland Museum of Natural History ans is a wetland of particular regional interest. It has been the site of aggressive attempts to control *Phragmites* and restore the natural condition of the marsh for several years. We are collaborating to provide monitoring data periodically.

ASSESSMENT AND OVERSIGHT

The Quality Assurance Project Plan (QAPP) for this program was originally written, signed by all co-PIs, and approved by USEPA 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 and at our February 22, 2018 meeting. In thoroughly reviewing the QAPP and SOPs in early 2018, crews found inconsistencies between the QAPP and SOPs and another handful of minor corrections and clarifications. PIs signed off on these changes at the 2018 PI meeting in Michigan in February. These fixes were incorporated into the QAPP in 2018 and PIs again signed off on the QAPP at the March 1, 2019, meeting in Michigan. The updated QAPP (QAPP_CWMII_rev 1) and SOPs were submitted to EPA in April of 2019.

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 (e.g., LSSU sent a lead technician to NRRI for training). Macroinvertebrate IDers communicate with each other via their own email list and assist each other with difficult identifications and other questions that arise.

- Training of all fish, macroinvertebrate, vegetation, bird, anuran 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 anurans. Training certification documents were archived with the lead PI and QA managers.

- GPS testing: Every GPS unit used during the 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 managers (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. The frequency of these consultations increased in 2018 and 2019 as high water levels made sampling particularly challenging.

- 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.

- 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. QC should be complete for all data by the spring semi-annual report submission each year.

- Linking of GPS points with field database: Inevitably, some errors occur when crew members type in GPS waypoint names and numbers. All non-linking points between these two databases were assessed and corrected in 2014, which took a hundred or more person-hours. We now have a more automated way to link GPS waypoints with data, crews are paying more attention to waypoint name/number accuracy, and the lat/longs for critical locations are being typed directly into the data management system. These three actions have greatly reduced number of GPS waypoints that cannot be linked to data in the DMS system.

- 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.), have shared specimens with other labs to assist them with identification. 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.

Example Water Quality QC Information

Laboratory Quality Assurances:
Water quality analyses from 2018 have been completed by the NRRI Central Analytical Laboratory, Central Michigan University's Wetland Ecology Laboratory, Grand Valley State University's Annis Water Resources Institute, Brockport's water quality lab, and Environment Canada's National Laboratory for Environmental Testing. Laboratory results are held to the criteria shown in Table 20.

Table 20. 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 two most recent project years is shown in Table 21. 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 21 below lists average RPD values for each year of the project (2011-2018). 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 21. Field duplicate sample variability for 2011-2018 in relative percent difference for water quality parameters with the acceptance criteria. Results < MDL were reported as ½ the MDL. The maximum expected RPD values are based on the MN Pollution Control Agency quality monitoring requirements for integrated assessments (https://www.pca.state.mn.us/sites/default/files/wq-s1-15n.pdf). Average RPD (n) min-max RPD.

Analyte	MDL	Maximum expected RPD	2011	2012	2013	2014	2015	2016	2017	2018
*Chlorophyll-a	--	30	45 (15) 0-99	36 (13) 5-106	46 (15) 16-124	36 (21) 0-97	45 (8) 18-88	31 (11) 0-105	47 (14) 0-130	37 (19) 0-161
Total phosphorus mg/L	0.002 NRRI, C-NLET 0.005 CMU	30	20 (13) 0-82	27 (13) 0.5-100	28 (17) 5-124	32 (19) 0-164	17 (9) 1-47	27 (10) 0-163	26 (14) 0-91	25 (19) 0-95
**Ortho-phosphorus mg/L	0.002 NRRI, C-NLET,CMU	10	18 (16) 0-67	16 (12) 0-80	16 (17) 0-67	44 (20) 0-200	49 (9) 4-190	26 (11) 0-80	35 (14) 0-100	11 (19) 0-111
Total nitrogen mg/L	0.010 mg/L	30	10 (13) 0-34	10 (13) 0-27	7 (17) 0.4-22	21 (19) 0-94	15 (8) 2-32	13 (11) 2-33	5 (14) 0.2-14	15 (19) 0-63
**NH4-N mg/L	0.01 mg/L	10	48 (16) 0-137	22 (13) 0-123	24 (17) 4-200	52 (20) 0-200	24 (9) 0-100	45 (11) 0-131	43 (14) 0-137	36 (19) 0-113
**NO2/NO3-N mg/L	0.004 mg/L	10	43 (16) 0-200	20 (13) 0-54	24 (17) 0-80	13 (20) 0-80	11 (9) 0-32	51 (11) 0-200	18 (14) 0-150	21 (19) 0-120
True color	--	10	12 (14) 0-43	5 (11) 0-21	3 (12) 1-8	13 (16) 0-40	7 (10) 0-21	6 (6) 0.4-18	5 (10) 0-20	6 (16) 0-28
chloride	1 mg/L	20	2 (12) 0-9	14 (11) 0.4-89	13 (13) 0-67	17 (20) 0-63	6 (10) 0.3-23	14 (8) 0-101	10 (12) 0.4-39	7 (19) 0-67

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

Notes:

Field duplicates are a second sample taken immediately after an initial sample in the exact same location to assess the site, sampling and possible temporal variability. Duplicate samples are collected in the exactly the same manner as the first sample, including the normal sampling equipment cleaning procedures. The relative percent difference (RPD) between the duplicate samples is calculated with the following equation:

RPD = (|Result 1 - Result 2|)/ ((Result 1 + Result 2)/2) x 100

Communication among Personnel

Regional team leaders and co-PIs continue to maintain close communication as the project is in its ninth year (fourth field season of round 2 sampling). The lead PI, all co-PIs, and many technicians attended an organizational meeting in Midland, Michigan on March 1, 2019. The PIs discussed issues pertaining to the upcoming field season, manuscript topics, and report products.

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 returning and experienced personal; if not, they either trained with a nearby crew or had a training team visit them for crew training. 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

The quality management system developed for this project has been fully implemented and co-PIs and their respective staff members continue to follow 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.

Despite the somewhat dangerous nature of this work, injury rates continue to be very low. The entire CWM team is relieved that crews continue to maintain an exemplary safety record. 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 often adverse conditions, and to conduct that sampling in accordance with strict QA procedures. Despite challenges such as high water levels, each field season has been successful.

LEVERAGED BENEFITS OF PROJECT (2010 – 2018)

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)

Evaluating Fish and Invertebrate Distribution in Great Lakes Coastal Wetlands - an Occupancy Modelling Approach: Led by University of Windsor graduate student Martin Jeanmougin, this project involves fish PIs Joseph Gathman, Carl Ruetz, Dennis Higgs and Jan Ciborowski. Occupancy modelling is a statistical approach that allows one to estimate the probability that a taxon is present in an area and the probability that it can be detected by sampling. Applying this approach to the invertebrate and fish CWM data could help us to identify important environmental factors influencing the likelihood that selected taxa occur in particular habitats and to more accurately estimate their distribution across the Great Lakes. Also, an analysis of the detection patterns can provide important information on potential biases in the protocols we use to sample the biota. The previous work done by K. Dykstra of Grand Valley State University (Carl Ruetz's lab) for the thesis on Yellow Perch distribution will be a good starting point for this project.

Genetic Barcodes for Wetland Macroinvertebrates: Surveillance of aquatic macroinvertebrates in the Great Lakes is of utmost importance. However, many organisms, particularly aquatic macroinvertebrates, lack information that can assist in their identification, whether through molecular barcodes or morphological characteristics. We are using previously collected aquatic macroinvertebrate samples from throughout the Great Lakes basins to generate genetic barcodes that will assist in identification of species (MOTUs) and expand the currently available molecular genetic databases. Our work is targeting specific groups to improve morphological identification to lowest taxonomic levels. Finally, we will be able to use these data to test the usefulness of metabarcoding for Great Lakes surveillance to provide managers with valuable monitoring information.

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 ran from fall 2016 through fall of 2019 to better determine functional indicators of Great Lakes coastal wetland usage by Great Lakes fish species. Sampling was 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 was 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 Anuran Metrics and Indicator Calculations: Avian and anuran 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 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, the Michigan Office of the Great Lakes, and the US Army Corp. of Engineers, has developed a DSS for wetlands along the US shoreline of the Great Lakes.

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

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

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

Buck Pond West and Buttonwood Creek, Lake Ontario, Sedge Meadow Restoration: These two wetlands in the Rochester Embayment AOC are actively being restored by a consortium involving Ducks Unlimited, The College at Brockport, NYS Department of Environmental Conservation, and the Town of Greece. CWM crews collected pre-restoration data as a benchmark site to help plan and implement restoration activities. Post-restoration data collection 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 anurans and from CWM on birds and anurans 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).

SOGL/SOLEC Indicators: CWM project PIs have developed a set of indicator metrics for the State of the Great Lakes/State of the Lakes Ecosystem Conference (SOLEC). These metrics 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 Marsh Monitoring projects have been scored according to several complementary indices that provide information about local and regional condition of existing wetlands.

Roxana Marsh Restoration (Lake Michigan): The University of Notre Dame (UND) team, led by graduate student Katherine O'Reilly and undergraduate Amelia McReynolds under the direction of project co-PI Gary Lamberti, leveraged the 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 the 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).

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. Results of this DNA analysis have been written up for publication.

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.

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

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

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

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

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

Student Research Support

Graduate Research with Leveraged Funding:

- Updating Dr. Gerald Mackie's key to Sphaeriidae (fingernail clams) of the Great lakes as informed by DNA analyses (University of Minnesota Duluth in collaboration with GLRI-funded work at Central Michigan University, the laboratory of Dr. Andrew Mahon).
- 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).
- Distribution of yellow perch in Great Lakes coastal wetlands (Grand Valley State University; with additional funding from GVSU).
- Variation in aquatic invertebrate assemblages in coastal wetland wet meadow zones of Lake Huron, of the Laurentian Great Lakes (University of Windsor; with additional funding from the University of Windsor).
- Influence of water level fluctuations and diel variation in dissolved oxygen concentrations on fish habitat use in Great Lakes coastal wetlands (University of Windsor; with additional funding from the University of Windsor).
- Long term dynamics of bird communities in Great Lakes coastal wetlands (University of Wisconsin-Green Bay with additional funding from Bird Studies Canada)
- Inferential measures for a quantitative ecological indicator of ecosystem health (University of Wisconsin-Green Bay)

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, TV and radio.
- 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; awarded Best Student Poster award at LSSU Research Symposium; presented at MI American Fisheries Society annual meeting).
- 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, (presented at MI American Fisheries Society annual meeting and Midwest Fish and Wildlife Conference).
- 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).
- Bathymetry and water levels in lagoonal wetlands of the Apostle Islands National Lakeshore (Northland College; additional funding from the National Park Service).

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 anuran 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)
- PFAS accumulation by *Dressenidae spp* in Great Lakes Coastal Wetlands (Central Michigan University)
- Development of a vegetation based IBI for Great Lakes Coastal Wetlands (Central Michigan University)

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).
- Nutrient uptake by *Phragmites australis* and native wetland plants (Central Michigan University).
- Comparison of the diagnostic accuracy two aquatic invertebrate field collection and laboratory sorting methods (University of Windsor, complete).
- Validation of a zoobenthic assemblage condition index for Great Lakes coastal wetlands (University of Windsor).
- Water depth-related variation in net ecosystem production in a Great Lakes coastal wet meadow (University of Windsor, completed).
- Anuran habitat use in the Lower Green Bay and Fox River Area of Concern (University of Wisconsin-Green Bay with support from GLRI/AOC funding).
- Impacts of European frog-bit invasion on wetland macroinvertebrate communities (Lake Superior State University; presented at Midwest Fish and Wildlife Conference).
- Effects of European frog-bit on water quality and fish assemblages in St. Marys River coastal wetlands (Lake Superior State University; presented at Midwest Fish and Wildlife Conference).

- Functional diversity of macroinvertebrates in coastal wetlands along the St. Marys River (Lake Superior State University; awarded Best Student Poster award at LSSU Research Symposium; presented at Midwest Fish and Wildlife Conference).

- A comparison of macroinvertebrate assemblages in coastal wetlands exposed to varying wave disturbance (Lake Superior State University; presented at MI American Fisheries Society annual meeting).

Jobs Created/Retained (cumulative since 2011):

- Principal Investigators (partial support): 20
- Post-doctoral researchers (partial support): 3 (0.25 – 0.5 FTE)
- Total graduate students supported on project (summer and/or part-time): 80
- Paid undergraduate internship (summer): 10
- Unpaid undergraduate internship (summer): 2
- Undergraduate students (summer and/or part-time): 126
- Technicians (summer and/or partial support): 90 (~45 FTE)
- Volunteers: 37

Total jobs at least partially supported: about 250 (plus 37 volunteers trained).

Presentations about the Coastal Wetland Monitoring Project (inception through 2018)

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.

Baldwin, R., B. Currell, and A. Moerke. 2014. Effects of disturbance history on resistance and resilience of coastal wetlands. Midwest Fish and Wildlife Conference, January, Kansas City, MO.

Baldwin, R., B. Currell, and A. Moerke. 2014. Effects of disturbance history on resistance and resilience of coastal wetlands. MI American Fisheries Society annual meeting, February, Holland, MI.

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.

Bozimowski, A.A. and D.G. Uzarski. 2017. Monitoring a changing ecosystem: Great Lakes coastal wetlands. Saginaw Bay Watershed Initiative Network's State of the Bay Conference.

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.

Brady, V.J., D.G. Uzarski, M.J. Cooper, D.A. Albert, N. Danz, J. Domke, T. Gehring, E. Giese, A. Grinde, R. Howe, A.H. Moerke, G. Niemi, H. Wellard-Kelly. 2018. How are Lake Superior's wetlands? Eight years, 100 wetlands sampled. State Of Lake Superior Conference. Houghton, MI. Oral Presentation.

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.

Cooper, M.J.. Great Lakes Coastal Wetlands. The White House Resilient Lands and Waters Initiative Roundtable. Washington, DC, November 17, 2016.

Cooper, M.J. Coastal Wetlands as Metabolic Gates, Sediment Filters, Swiss Army Knife Habitats, and Biogeochemical Hotspots. Science on Tap, Ashland, WI, March 21, 2017.

Cooper, M.J. Translating Science Into Action in the Great Lakes. Marvin Pertzik Lecture Series. Northland College, May 2016.

Cooper, M.C., C. Hippensteel, D.G. Uzarski, and T.M. Redder. Developing a decision support tool for Great Lakes coastal wetlands. LCC Coastal Conservation Working Group Annual Meeting, Great Lakes Environmental Research Laboratory, Ann Arbor, MI, Oct. 6, 2016.

Cooper, M.J., Brady, V.J., Uzarski, D.G., Lamberti, G.A., Moerke, A.H., Ruetz, C.R., Wilcox, D.A., Ciborowski, J.J.H., Gathman, J.P., Grabas, G.P., and Johnson, L.B. An Expanded Fish-Based Index of Biotic Integrity for Great Lakes Coastal Wetlands. International Association for Great Lakes Research 60th Annual Meeting, Detroit, MI, May 15-19, 2017.

Cooper, M.J., D.G. Uzarski, and A. Garwood. Great Lakes Coastal Wetland Monitoring." Webinar hosted by Michigan Department of Environmental Quality, April 14, 2017. 78 attendees.

Cooper, M.J. The Role of Wetlands in Maintaining Water Quality. Briefing to the International Joint Commission, Ashland, WI, September 26, 2019.

Cooper, M.J., V.J. Brady, and D.G. Uzarski. Great Lakes Coastal Wetland Monitoring. Plenary Presentation, Great Lakes Coastal Wetland Symposium, Oregon, OH, September 19, 2019.

Cooper, M.J. and S. Johnson. Life on the Soggy Edges. Madeline Island Wilderness Preserve Lecture Series, Madeline Island Museum, La Pointe, WI, June 19, 2019.

Curell, Brian. 2014. Effects of disturbance frequency on macroinvertebrate communities in coastal wetlands. MI American Fisheries Society annual meeting, February, Holland, MI.

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.

Daly, D., T. Dunn, and A. Moerke. 2016. Effects of European frog-bit on water quality and fish assemblages in St. Marys River wetlands. Midwest Fish and Wildlife Conference, Grand Rapids, MI. January 24-27.

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.

Dunn, T., D. Daly, and A. Moerke. 2016. Impacts of European frog-bit invasion on Great Lakes wetlands macroinvertebrate communities. Midwest Fish and Wildlife Conference, Grand Rapids, MI. January 24-27.

Dykstra, K.M., C.R. Ruetz III, M.J. Cooper, and D.G. Uzarski. 2018. Occupancy and detection of yellow perch in Great Lakes coastal wetlands. Poster presentation at the Annual Meeting of the Society for Freshwater Science, Detroit, Michigan. May 20-24.

Dykstra (Emelander), K.M., C.R. Ruetz III, M.J. Cooper, and D.G. Uzarski. 2018. Occupancy and detection of yellow perch in Great Lakes coastal wetlands: preliminary results. Poster presentation at the annual meeting of the Michigan Chapter of the American Fisheries Society, Port Huron, Michigan. February 13-14.

Elliot, L.H., A.M. Bracey, G.J. Niemi, D.H. Johnson, T.M. Gehring, E.E. Gnass Giese, G.P. Grabas, R.W. Howe, C.J. Norment, and D.C. Tozer. Habitat Associations of Coastal Wetland Birds in the Great Lakes Basin. American Ornithological Society Meeting, East Lansing, Michigan. Poster Presentation. 31 July-5 August 2017.

Elliott, L.H., A. Bracey, G. Niemi, D.H. Johnson, T. Gehring, E. Giese, G. Grabas, R. Howe, C. Norment, and D.C. Tozer. 2018. Hierarchical modeling to identify habitat associations of secretive marsh birds in the Great Lakes. IAGLR Conference, Toronto, Canada. Oral Presentation. 18-22 June 2018.

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., R. Howe, A. Wolf, and G. Niemi. 2017. Breeding Birds and Anurans of Dynamic Green Bay Coastal Wetlands. State of Lake Michigan Conference, Green Bay, Wisconsin. Oral Presentation. 8 November 2017.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., R.W. Howe, A.T. Wolf, N.A. Miller, and N.G. Walton. 2014. Using Bird Data to Assess Condition of Western Great Lakes Forests. Midwest Bird Conservation and Monitoring Workshop, Port Washington, Wisconsin. Poster Presentation. 4-8 August 2014.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.

Harrison, A.M., M.J. Cooper, and D.G. Uzarski. 2019. Spatial and temporal (2011-2018) variation of water quality in Great Lakes coastal wetlands. International Association for Great Lakes Research. Brockport, NY. Presentation.

Hein, M.C. and Cooper, M.J. Untangling drivers of chlorophyll a in Great Lakes coastal wetlands. International Association for Great Lakes Research 60th Annual Meeting, Detroit, MI, May 15-19, 2017.

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, B., A. Wolf, E. Giese, V. Pappas, B. Kupsky, M. Grimm, and N. Van Helden. 2018. Lower Green Bay & Fox River Area of Concern Wildlife and Habitat Assessment Tools. AOC RAP Meeting, Green Bay, Wisconsin. Oral Presentation. 25 April 2018.

Howe, B., A. Wolf, E. Giese, V. Pappas, B. Kupsky, M. Grimm, and N. Van Helden. 2018. Assessing the Fish and Wildlife Habitat BUI for the Lower Green Bay and Fox River Area of Concern. Annual Great Lakes Areas of Concern Conference, Sheboygan, Wisconsin. Oral Presentation. 16 May 2018.

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.

Johnson, Z., M. Markel, and A. Moerke. 2019. Functional diversity of macroinvertebrates in coastal wetlands along the St. Marys River. Midwest Fish and Wildlife Conference, Cleveland, OH.

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.

Kneisel, A.N., M.J. Cooper, and D.G. Uzarski. 2017. The impact of Phragmites australis invasion on Great Lakes coastal wetlands. 60th International Conference on Great Lakes Research, Detroit, MI. May. Presentation.

Kneisel, A.K., M.J. Cooper, D.G. Uzarski. 2018. Coastal wetland monitoring data as a resource for invasive species management. ELLS-IAGLR Big Lakes Small World Conference. Évian, France. September. Poster.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.

Kowalke, C.J. and D.G. Uzarski. 2019. Assessing the competitive impacts of invasive round goby on lake whitefish in northern Lake Michigan. International Association for Great Lakes Research. Brockport, NY. Poster.

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.

Markel, M., Z. Johnson, and A. Moerke. 2019. A comparison of macroinvertebrate assemblages in coastal wetlands exposed to varying wave disturbance. March 13-15, Gaylord, MI.

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.

Moerke, A. 2015. Coastal wetland monitoring in the Great Lakes. Sault Naturalist meeting, Sault Sainte Marie, MI; approximately 40 community members present.

Moore, L.M., M.J. Cooper, and D.G. Uzarski. 2017. Nutrient limitation in Great Lakes coastal wetlands: gradients and their influence. 60th International Conference on Great Lakes Research, Detroit, MI. May 17. Presentation.

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.

Newman, W.L., L.P. Moore, M.J. Cooper, D.G. Uzarski, and S.N. Francoeur. 2019. Nitrogen-Fixing Diatoms as Indicators of Historical Nitrogen Limitation in Laurentian Great Lakes Coastal Wetlands. Society for Freshwater Science. Salt Lake City, UT. Presentation.

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.

Redder, T.M., D.G. Uzarski, V.J. Brady, M.J. Cooper, and T.K. O'Donnell. 2018. Application of data management and decision support tools to support coastal wetland management in the Laurentian Great Lakes. National Conference on Ecosystem Restoration. New Orleans, LA. August 26-30, 2018. Oral 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.

Sierzen, M., L. Schoen, J. Hoffman, J. Kosiara and D. Uzarski. 2018. Tracing multi-habitat support of coastal fishes. Association for the Sciences of Limnology and Oceanography-Ocean Sciences Meeting. Portland, OR. February 2018. Oral 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.

Tozer, D.C., M. Falconer, A. Bracey, E. Giese, T. Gehring, G. Grabas, R. Howe, G. Niemi, and C. Norment. 2018. Detecting and monitoring elusive marsh breeding birds in the Great Lakes. IAGLR Conference, Toronto, Canada. Oral Presentation. 18-22 June 2018. (INVITED).

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, M.J. Cooper, D.A. Wilcox, A.A. Bozimowski. 2017. Leveraging landscape level monitoring and assessment program for developing resilient shorelines throughout the Laurentian Great Lakes. Society of Wetland Scientists Annual Meeting. San Juan, Puerto Rico. June. 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.

Uzarski, D.G. 2017. Emerging Issues in Wetland Science. Michigan Wetland Association Conference. Gaylord, Michigan. Plenary Presentation.

Uzarski, D.G. 2018. Monitoring multiple biological attributes in Great Lakes coastal wetlands: database access for invasive species management. Association of State Wetlands Managers. Webinar Presentation.

Uzarski, D.G. Global Significance & Major Threats to the Great Lakes. 2018. Frey Foundation Strategic Learning Session. The Great Lakes: Global Significance, Major Threats & Innovative Solutions. Petoskey, MI.

Uzarski, D.G., V.J. Brady, M.J. Cooper, et al. 2018. The Laurentian Great Lakes Coastal Wetland Monitoring Program: Landscape level assessment of ecosystem health. ELLS-IAGLR Big Lakes Small World Conference. Évian, France. September. Poster

Uzarski, D.G. and M.J. Cooper. 2019. Using a decision tree approach to inform protection and restoration of Great Lakes coastal wetlands. International Association for Great Lakes Research. Brockport, NY.

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)

Winter, C., T.K. O'Donnell, D.G, Uzarski, V.J. Brady, M.J., Cooper, A. Garwood, J.L. Utz, and J. Neal. 2017. Great Lakes coastal wetland monitoring: moving from assessment to action. Ecological Society of America Annual Conference. Portland, OR. Oral Presentation.

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

Carson, D.B., S.C. Lishawa, N.C. Tuchman, A.M. Monks, B.A. Lawrence, and D.A. Albert. 2018. Harvesting invasive plants to reduce nutrient loads and produce bioenergy: an assessment of Great Lakes coastal wetlands. Ecosphere 9(6):e02320. 10.1002/ecs2.2320

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

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

Cooper, M.J., G.M. Costello, S.N. Francoeur, and G.A. Lamberti. 2016 Nitrogen limitation of algal biofilms in coastal wetlands of Lakes Michigan and Huron. *Freshwater Science* 35(1):25–40.

Cooper, M.J., G.A. Lamberti, A.H. Moerke, C.R. Ruetz, D.A. Wilcox, V.J. Brady, T.N. Brown, J.J.H. Ciborowski, J.P. Gathman, G.P. Grabas, L.B. Johnson, and D.G. Uzarski. 2018. An expanded fish-based index of biotic integrity for Great Lakes coastal wetlands. *Environmental Monitoring and Assessment* 190: 580.

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.

Gaul, W. 2017. Inferential measures for a quantitative ecological indicator of ecosystem health. M.Sci. Thesis, University of Wisconsin, Green Bay, Wisconsin. 35 pp.

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

Gnass Giese, E.E., R.W. Howe, A.T. Wolf, and G.J. Niemi. 2018. Breeding birds and anurans of dynamic coastal wetlands in Green Bay, Lake Michigan. Journal of Great Lakes Research (Green Bay Special Issue): 44(5):950-959. https://doi.org/10.1016/j.jglr.2018.06.003

Harrison, A.M., A.J. Reisinger, M.J. Cooper, V.J. Brady, J.J. Ciborowski, K.E. O'Reilly, C.R. Ruetz, D.A. Wilcox, and D.G. Uzarski. 2019. A Basin-Wide Survey of Coastal Wetlands of the Laurentian Great Lakes: Development and Comparison of Water Quality Indices. Wetlands, pp.1-13.

Horton, D.J., K.R. Theis, D.G. Uzarski, D.R. Learman 2018. Microbial community structure and microbial networks correspond to nutrient gradients within coastal wetlands of the Great Lakes. bioRxiv, 217919

Howe, R.W., E.E. Gnass Giese, and A.T. Wolf. 2018. Quantitative restoration targets for fish and wildlife habitats and populations in the Lower Green Bay and Fox River AOC. Journal of Great Lakes Research (Green Bay Special Issue): 44(5):883-894. https://doi.org/10.1016/j.jglr.2018.05.002

Kovalenko, K.E., L.B. Johnson, V.J. Brady, J.H.H. Ciborowski, M.J. Cooper, J.P. Gathman, G.A. Lamberti, A.H. Moerke, C.R. Ruetz III, and D.G. Uzarski. 2018. Hotspots and bright spots in functional and taxonomic fish diversity. Freshwater Science.

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.

Langer, T.A., M.J. Cooper. L.S. Reisinger, A.J. Reisinger, and D. G. Uzarski. 2017. Water depth and lake-wide water level fluctuation influence on α- and β-diversity of coastal wetland fish communities. Journal of Great Lakes Research, In Press. 44(1): 71-76.

Lemein, T., D.A. Albert, and E.D. Tuttle. 2017. Coastal wetland vegetation community classification and distribution across environmental gradients through the Laurentian Great Lakes. Journal of Great Lakes Research 43 (4): 658-669.

Reisinger, A.J., A.M. Harrison, M.J. Cooper, C.R. Ruetz, D.G. Uzarski, D.A. Wilcox. In Press. A basin-wide survey of coastal wetlands of the Laurentian Great Lakes: Development and comparison of water quality indices. Wetlands. Early Online August 5, 2019.

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.

Sierszen M.E., L.S. Schoen, J.M. Kosiara*, J.C. Hoffman, M.J. Cooper, and D.G. Uzarski. 2018. Relative contributions of nearshore and wetland habitats to coastal food webs in the Great Lakes. J. Great Lakes Res, https://doi.org/10.1016/j.jglr.2018.11.006

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.*

Schock, N.T. A.J. Reisinger, L.S. Reisinger, M.J. Cooper, J.J.H. Cibrowski, T.M. Gehring, A. Moerke, D.G. Uzarski. ACCEPTED FOR PUBLICATION. Relationships between the distribution of the invasive faucet snail (*Bithynia tentaculata*) and environmental factors in Laurentian Great Lakes coastal wetlands. *Biological Invasions*.

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

Tozer, D.C., C.M. Falconer, A.M. Bracey, E.E. Gnass Giese, G.J. Niemi, R.W. Howe, T.M. Gehring, and C.J. Norment. 2017. Influence of call broadcast timing within point counts and survey duration on detection probability of marsh breeding birds. Avian Conservation and Ecology 12(2):8.

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. 2017. Coastal Wetland Amphibians in State of the Great Lakes 2017 Technical Report: Indicators to assess the status and trends of the Great Lakes ecosystem on pages 146-162.

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. 2017. Coastal Wetland Birds in State of the Great Lakes 2017 Technical Report: Indicators to assess the status and trends of the Great Lakes ecosystem on pages 163-179.

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.

Uzarski, D.G., D.A. Wilcox, V.J. Brady, M.J. Cooper, D.A. Albert, J.J.H. Ciborowski, N.P. Danz, A. Garwood, J.P. Gathman, T.M. Gehring, G.P. Grabas, R.W. Howe, G.A. Lamberti, A.H. Moerke, G.J. Niemi, C.R. Ruetz, D.C. Tozer, and T.K. O’Donnell, ACCEPTED FOR PUBLICATON. Leveraging landscape level monitoring and assessment program for developing resilient shorelines throughout the Laurentian Great Lakes. *Wetlands*.

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

Cooper, M. G.A. Lamberti, A.H. Moerke, C.R. Ruetz III, D.A. Wilcox, V. J. Brady, T.N. Brown, J.J.H. Ciborowski, J.P. Gathman, G.P. Grabas, L.B. Johnson, D.G. Uzarski. 2018. An Expanded Fish-Based Index of Biotic Integrity for Great Lakes Coastal Wetlands. Env. Monit. Assess. 190:580. DOI: https://doi.org/10.1007/s10661-018-6950-6.

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.

Gaul, W. 2017. Inferential measures for a quantitative ecological indicator of ecosystem health. M.Sc. Thesis. University of Wisconsin-Green Bay, Green Bay, WI. 184 pp.

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.

Harrison, A.M., A.J. Reisinger, M.J. Cooper, V.J. Brady, J.J. Ciborowski, K.E. O’Reilly, C.R. Ruetz, D.A. Wilcox, and D.G. Uzarski. 2019. A Basin-Wide Survey of Coastal Wetlands of the Laurentian Great Lakes: Development and Comparison of Water Quality Indices. Wetlands, pp.1-13.

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, H.G., Niemi, G.J., Regal, R.R., Tozer, D.C., Gehring, T.M., Howe, R.W. and Norment, C.J. 2017. Influence of Local, Landscape, and Regional Variables on Sedge and Marsh Wren Occurrence in Great Lakes Coastal Wetlands. Wetlands, 37(3): 447-459.

R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL. https://www.R-project.org/.

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.