Implementing the Great Lakes Coastal Wetland Monitoring Program

Semiannual Progress Report

October 1, 2018 – March 31, 2019

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

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

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

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

INTRODUCTION

Monitoring the biota and water quality of Great Lakes coastal wetlands began as a project funded under the Great Lakes Restoration Initiative on September 10, 2010. The project had the primary objective of implementing a standardized basin-wide coastal wetland monitoring program. Our first five years of sampling (2011-2015) set the baseline for future sampling years and showed the power of the datasets that can be used to inform decision-makers on coastal wetland conservation and restoration priorities throughout the Great Lakes basin. During round 1, we 1) developed a database management system; 2) developed a standardized sample design with rotating panels of wetland sites to be sampled across years, accompanied by sampling protocols, Quality Assurance Project Plans (QAPPs), and other methods documents; and 3) developed background documents on the indicators.

We have now entered the second phase of this work. The status of the work has been changed from a project to a sampling program, and we are sampling all the wetlands again for the second round of this work. During this second round (2016-2020), we are investigating adjustments to our indicators to ensure that water level fluctuations are taken into account. We are also increasing our assistance to restoration projects.

Summary of Round 1 of sampling:
Our first round of sampling, in the project phase, began with the development of our Quality Assurance Project Plan, developing the site selection mechanism, selecting our sites, extensively training all field crew members, and finally beginning wetland sampling. After a few methods adjustments, we updated our QAPP and have kept it updated, although relatively minor changes have had to be made 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-interface database specifically designed to hold the data.

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

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

PROGRAM ORGANIZATION

Figure 1 shows our program organization and personnel chart.

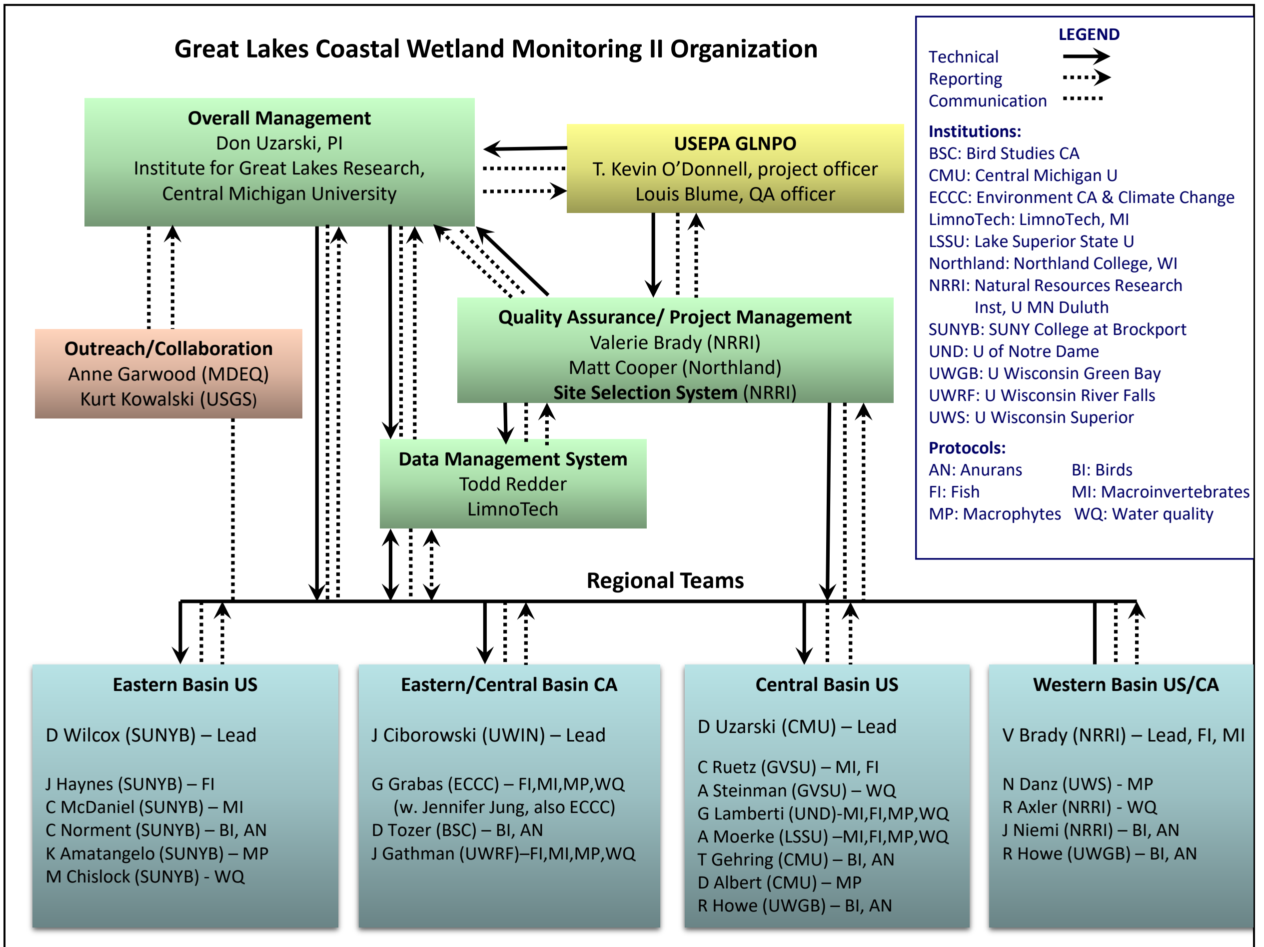

Figure 1. Organizational chart for the program showing lines of technical direction, reporting, and communication separately.

PROGRAM TIMELINE

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

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

Tasks	‘15	2016				2017				2018				2019				2020			
	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F
Funding received	X																				
PI meeting		X				X				X				X				X			X
Site selection system updated		X				X				X				X				X			
Site selection for summer			X			X				X				X				X			
Sampling permits acquired			X				X				X				X				X		
Data entry system updated		X	X	X	X																
Field crew training			X	X			X	X			X	X			X	X			X	X	
Wetland sampling			X	X			X	X			X	X			X	X			X	X	
Mid-season QA/QC evaluations				X				X				X				X				X	
Sample processing & QC					X	X			X	X			X	X			X	X			X
Data QC & upload to GLNPO						X	X			X	X			X	X			X	X		X
Report to GLNPO			X		X		X		X		X		X		X		X		X		X

Table 2. GLRI Action Plan II of Measure of Progress. Wetlands are sampled during the summer.

GLRI Action Plan II Measure of Progress		**Reporting Period (Oct. 1, 2018 – Mar. 31, 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	192*	75% completed

* 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. This summer we will be sampling the sites sampled in 2014. The sites most likely to change between sampling rounds are the 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 may also result 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 ha., had herbaceous vegetation, and had (or appeared to have) a lake connection were placed into the site selection random sampling rotation (Table 3). 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 have proven to be sampleable thus far, we expect that the total number of sampleable wetlands will be between 900 and 1000 in any given year; we sample roughly 200 of these (one fifth) per year.

Table 3. 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 more wetlands in the US than in Canada, with an even greater percent of US wetland area (Table 3). We speculate that this is partly due to poor representation of Georgian Bay (Lake Huron) wetlands in the sampleable wetland database. This area is also losing wetlands rapidly due to a combination of glacial rebound and topography that limits the potential for coastal wetlands to migrate downslope during periods of low lake levels. Another component of this US/CA discrepancy is the lack of coastal wetlands along the Canadian shoreline of Lake Superior due to the rugged topography and geology. A final possibility is unequal loss of wetlands between the two countries, but this has not been investigated.

Strata

Geomorphic classes

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

Regions

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

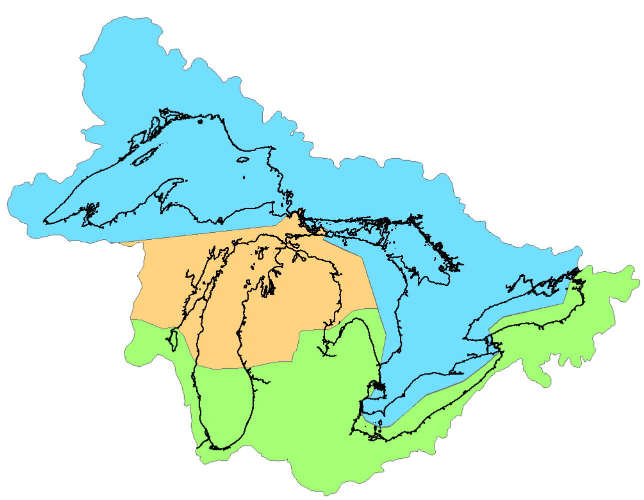

Figure 2. Divisions of lakes into regions. Note that stratification is by region *and* lake, so northern Lake Erie is not in the same region as Lake Superior, etc.

Panelization

Randomization

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

In 2012, sites previously assigned to panels for sampling were assigned to sub-panels for re-sampling. The project design's five year rotation with a 10% re-sampling rate requires five panels, *A-E*, and ten sub-panels, *a-j*. If 10% of each panel's sites were simply randomly assigned to sub-panels in order *a-j*, sub-panel *j* would have a low count relative to other sub-panels. To avoid this, the order of sub-panels was randomized for each panel during site-to-sub-panel assignment, as can be seen in the random distribution of the '20' and '21' values in Table 4.

For the first five-year cycle, sub-panel *a* will be re-sampled in each following year, so the 20 sites in sub-panel *a* of panel *A* were candidates for re-sampling in 2012. The 20 sites in sub-panel *a* of panel *B* were candidates for re-sampling in 2013, and so on. In 2016, when panel *A* was sampled for the second time, the 21 sites in sub-panel *a* of panel *E* were candidates for re-sampling. Thus in summer 2019, when panel *D* is being sampled for the second time, the 21 sites in sub-panel *b* of panel *C* will be candidates for re-sampling. And so forth. The total panel and sub-panel rotation covers 50 years.

Table 4. Sub-panel re-sampling, showing year of re-sampling for sub-panels *a-c*.

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

Workflow states

Each site was assigned a particular 'workflow' status. During the field season, sites selected for sampling in the current year will move through a series of sampling states in a logical order, as shown in Table 5. The *data_level* field is used for checking that all data have been received and their QC status. Users set the workflow state for sites in the web tool, although some states can also be updated by querying the various data entry databases.

Team assignment

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

Table 5. Workflow states for sites listed in the Site Status table within the web-based site selection system housed at NRRI. This system tracks site status for all taxonomic groups and teams for all sites to be sampled in any given year. Values have the following meanings: -1: site will not generate data, 0: site may or may not generate data, 1: site should generate data, 2: data received, 3: data QC'd.

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

Field maps

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

Browse map

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

2019 Site Selection

For 2019, 243 sites have been initially selected for sampling (Figure 3). Of these, 28 are benchmark sites. Another 20 sites are resample sites and 20 are 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 will help ensure that most crews sample them, allowing more complete comparison of year-to-year variation when the sites are sampled again the next year. Because the vast majority of the 2019 sites were sampled in 2014, we do not expect very many sites to be dropped due to inaccessibility or not meeting our sampling criteria. However, high lake levels may result in some sites being unsampleable in 2019 as they have been since 2016.

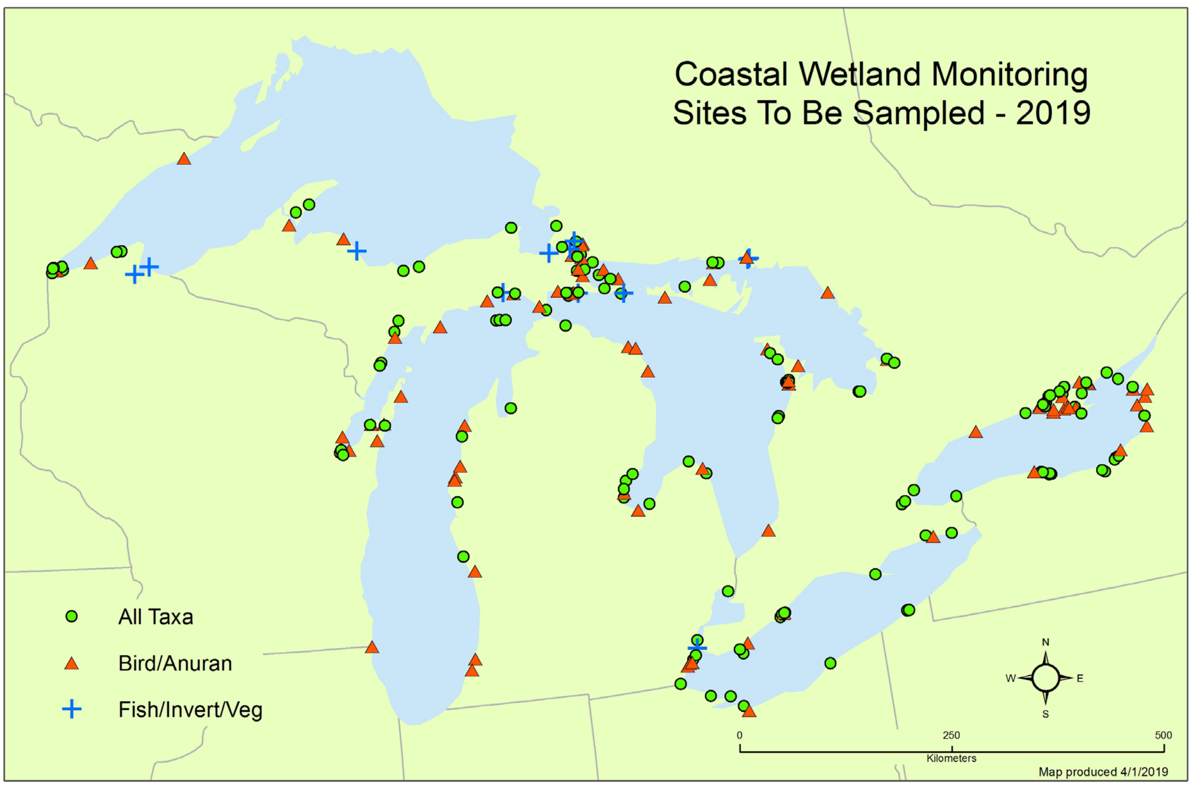

Figure 3. Locations of the 243 Great Lakes coastal wetlands to be sampled in 2019, color-coded by taxonomic groups. Sites assigned only to bird and anuran crews (due to their greater sampling capacity) are shown with a red triangle sign.

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

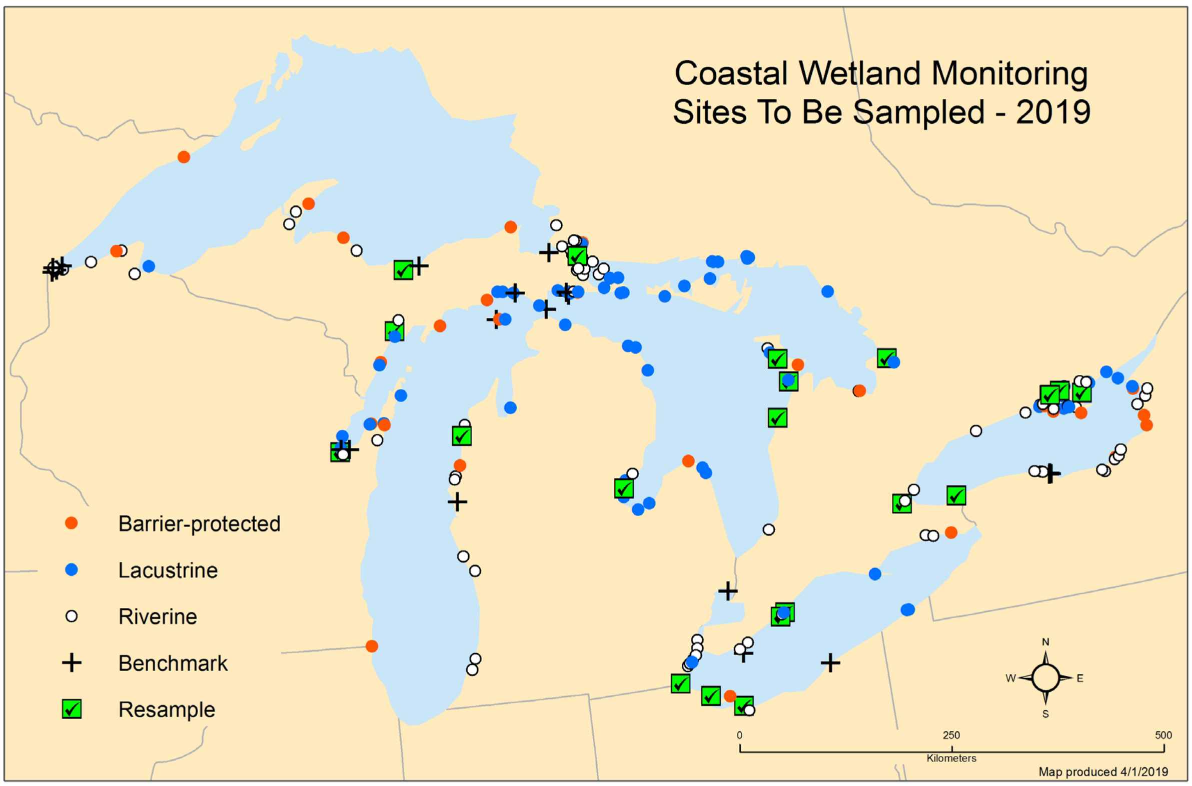

Figure 4. Locations of the 243 Great Lakes coastal wetlands to be sampled in 2019, color-coded by site type. See text for description of site types.

We now have 85 sites for which at least some of their sampling is designated as "benchmark." Of these sites, 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.

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

TRAINING

All personnel responsible for sampling invertebrates, fish, macrophytes, birds, amphibians, and water quality received training and were certified prior to sampling in 2011. During that first year, teams of experienced trainers held training workshops at several locations across the Great Lakes basin to ensure that all PIs and crews were trained in Coastal Wetland Monitoring methods. Now that PIs and crew chiefs are experienced, field crew training is being handled by each PI at each regional location; if there is significant crew turnover, new crew members may either train with an experienced crew or have the experienced trainers return for their crew training. All crew members must pass all training tests each year, and PIs conduct mid-season QC. As has become standard protocol, the trainers will always be available via phone and email to answer any questions that arise during training sessions or during the field season.

The following is a synopsis of the training to be conducted by PIs this spring (2019): Each PI or field crew chief trains all field personnel on meeting the data quality objectives for each element of the project; this includes reviewing the most current version of the QAPP, covering site verification procedures, providing hands-on training for each sampling protocol, and reviewing record-keeping and archiving requirements, data auditing procedures, and certification exams for each sampling protocol. All field crew members are required to pass all training certifications before they are allowed to work unsupervised. Those who do not pass all training aspects are only allowed to work under the supervision of a crew leader who has passed all training certifications.

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

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

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

Training on data entry and data QC was provided by Valerie Brady and Terry Brown through a series of conference calls/webinars during the late summer, fall, and winter of 2011. All co-PIs and crew leaders responsible for data entry participated in these training sessions and each regional laboratory has successfully uploaded data each year. Additional training on data entry, data uploading, and data QC was provided in 2016 with the implementation of the updated version of the data entry/data archiving system by Todd Redder at LimnoTech. Training on data entry and QC continues via webinar as needed for new program staff.

Certification

To be certified in a given protocol, individuals must pass a practical exam. Certification exams are conducted in the field in most cases, either during training workshops or during site visits early in the season. When necessary, exams are supplemented with photographs (for fish and vegetation) or audio recordings (for bird and amphibian calls). Passing a given exam certifies the individual to perform the respective sampling protocol(s). Since not every individual is responsible for conducting every sampling protocol, crew members are only tested on the protocols for which they are responsible. Personnel who are not certified (e.g., part-time technicians, new students, volunteers) are not allowed to work independently or to do any taxonomic identification except under the direct supervision of certified staff members. Certification criteria are listed in the project QAPP. For some criteria, demonstrated proficiency during field training workshops or during site visits is considered adequate for certification. Training and certification records for all participants are collected by regional team leaders and copied to Drs. Brady and Cooper (QC managers) and Uzarski (lead PI). Note that the training and certification procedures explained here are separate from the QA/QC evaluations explained in the following section. However, failure to meet project QA/QC standards requires participants to be re-trained and re-certified.

Documentation and Record

All site selection and sampling decisions and comments are archived in the site selection system (see "site selection"). These include comments and revisions made during the QC oversight process.

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

Web-based Data Entry System

The CWMP has been using a web-based data management system (DMS) that was originally developed by NRRI in 2011 to hold 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, utilizes Microsoft's Active Server Pages .NET (ASP.NET) web application framework running on a Windows 2012 Server and hosted on a virtual machine at Central Michigan University (CMU). The open source PostgreSQL Relational Database Management System (RDMS) with PostGIS spatial extensions is used to provide storage for all CWMP data on the same Windows 2012 server that hosts the web application.

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

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

- Automated processes for individual users to request and confirm accounts;
- An account management page where a limited group of users with administrative privileges can approve and delete user accounts and change account settings as needed;
- Numerous validation rules employed to prevent incorrect or duplicate data entry on the various data entry/editing forms;
- Custom form elements to mirror field sheets (e.g. the vegetation transects data grid), which makes data entry more efficient and minimizes data entry errors;
- Domain-specific "helper" utilities, such as generation of fish length records based on fish count records;

- Dual-entry inconsistency highlighting for amphibian and bird groups using dual-entry for quality assurance; and
- Tools for adding new taxa records or editing existing taxa records for the various taxonomic groups.

The CWMP data management system also provides separate webpages that allow researchers to download "raw" data for the various taxonomic groups as well as execute and download custom queries that are useful for supporting dataset review and QA/QC evaluations as data entry proceeds during, and following, each field season. Users 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 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. We are working to fully implement and test automated algorithms for calculating IBI metric scores for vegetation, invertebrates, and fish on a regular schedule as data are entered and pass through the QA/QC process.

Raw data downloads are available in both Microsoft (MS) Excel spreadsheet and MS Access database formats, while custom query results are available in spreadsheet format only. All available data/query export and download options are automatically regenerated every night, and users have the option of either downloading the last automated export or generating a new export that provides a snapshot of the database at the time the request is made (the former option is much faster). 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 bi-annual schedule, planned to occur 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 the GLRI. CWMP data management support staff generate and provide to GLNPO and its 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 contractors to update the master version of the Microsoft Access database used to support custom querying and reporting of the monitoring datasets.

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

RESULTS-TO-DATE (2011-2018, with exceptions noted)

A total of 176 wetlands were sampled in 2011, with 206 sampled in 2012, 201 in 2013, 216 in 2014, 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 6). 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. We are now well underway sampling these wetlands a second time for the second complete round of coastal wetland assessment, 2016-2020. Round two sampling began in 2016 with 192 wetlands sampled and continued in 2017 with 209 wetlands sampled and 2018 with 192 wetlands sampled.

In all years, more wetlands are 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 6). When compared to the total number of wetlands targeted to be sampled by this project (Table 3), we are achieving our goals of sampling 20% of US wetlands per year, both by count and by area. However, each year 60-65% of total sites sampled are US coastal wetlands, with 75-80% of the wetland area sampled on the US side. Overall, not yet correcting for sites that have been sampled more than once, we have sampled nearly all of the large, surface-connected Great Lakes coastal emergent wetlands by count and by area. A few wetlands cannot currently be sampled due to a lack of safe access or a lack of permission to cross private lands.

Teams were able to sample more sites in 2014 than in the prior years 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. Beginning in 2015 and continuing through 2018, water depths in some coastal wetlands had become so deep that crews had difficulty finding areas shallow enough to set fish nets in vegetation types typically sampled for fish (cattail, bulrush, SAV, floating leaf, etc.). 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.

Table 6. 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%
CA total Round 2	**200**	**34%**	**15,693**	**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%
US total Round 2	**393**	**66%**	**73,257**	**82%**
Overall Totals Round 1	**1010**		**151,446**	
Overall Totals Round 2	**593**		**88,950**	

We can now compile good statistics on Great Lakes coastal wetlands because we have sampled nearly 100% of the hydrologically-connected Great Lakes coastal wetlands greater than 4 ha. that can be safely accessed by our crews. The following information is from Round 1 sampling (2011 – 2015).

Wetlands contained approximately 25 bird species on average; some sampled benchmark sites had as few as 1 species, but richness at high quality sites was as great as 60 bird species (Table 7). There are many fewer anuran species in the Great Lakes (8 total), and coastal wetlands averaged about 4 species per wetland, with some benchmark wetlands containing no calling anurans (Table 7). However, there were wetlands where all 8 calling anuran species were heard over the three sampling dates.

Table 7. Bird and anuran species in wetlands; summary statistics by country. Data from 2011 through 2018.

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
Amphibians					
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 8) 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. These data include the benchmark sites, many of which are in need of or undergoing restoration, so the minimum number of species is quite low with a wetland on Lake Huron having no birds observed.

Calling 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 calling anuran species regardless of lake (Table 8). Similarly, there was little variability by lake in maximum or minimum numbers of species. At some benchmark sites, and occasionally during unusually cold spring weather, no calling anurans were detected.

Table 8. 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	0	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 9). 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; Figure 5). 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 9. Total fish species in wetlands, and non-native species; summary statistics by country for sites sampled from 2011 through 2018.

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.

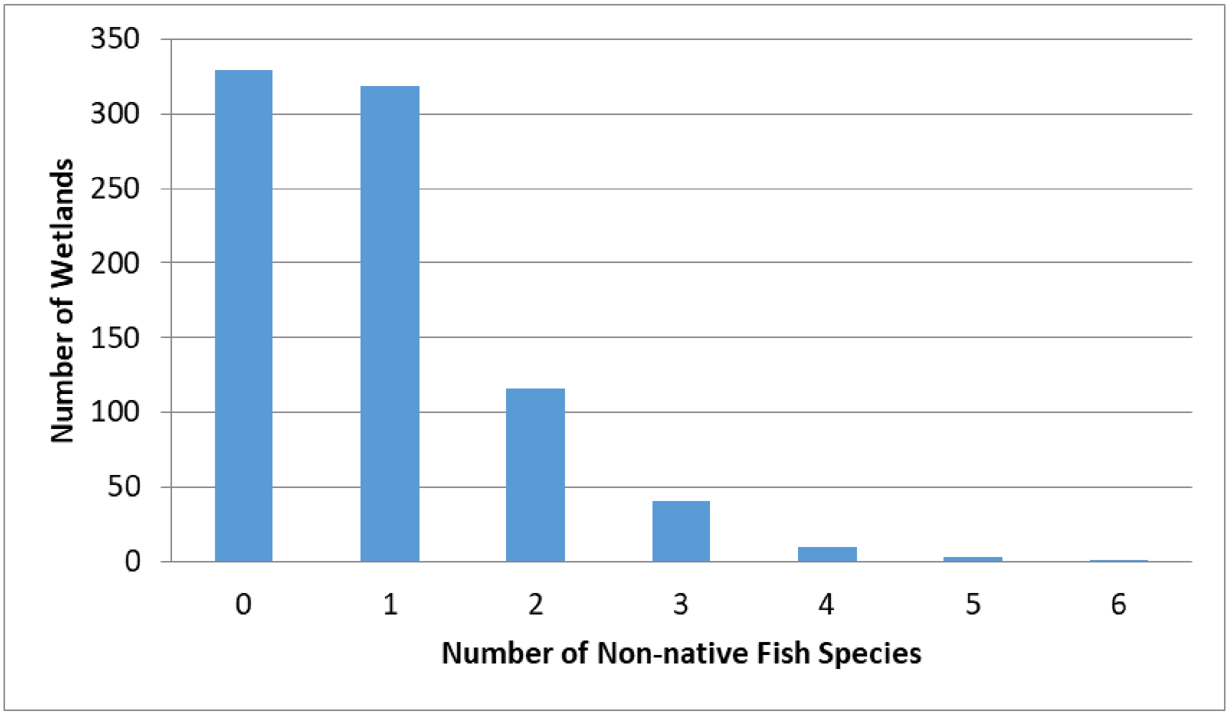

Figure 5. Number of Great Lakes coastal wetlands containing non-native fish species. Data from 2011 through 2018.

Total fish species did not differ greatly by lake, averaging 11-13 species per wetland (Table 10). 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 species captured (0.6 non-native 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 and all lakes had some wetlands in which we caught no non-native fish. This result does not necessarily mean that these wetlands are free of non-natives, unfortunately. Our single-night net sets do not catch all fish species in wetlands, and some species are quite adept at avoiding passive capture gear. For example, common carp can 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 10. 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 11), 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 found in coastal wetlands was less than 1, with a maximum of no more than 5 taxa (Table 11). 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 11. 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 restoration sites in these summaries. We are finding an average of about 35-43 macroinvertebrate taxa in wetlands, with lakes Ontario and Erie having lower averages than the upper lakes (Table 12). 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, Huron, and Ontario 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 12. 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.

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

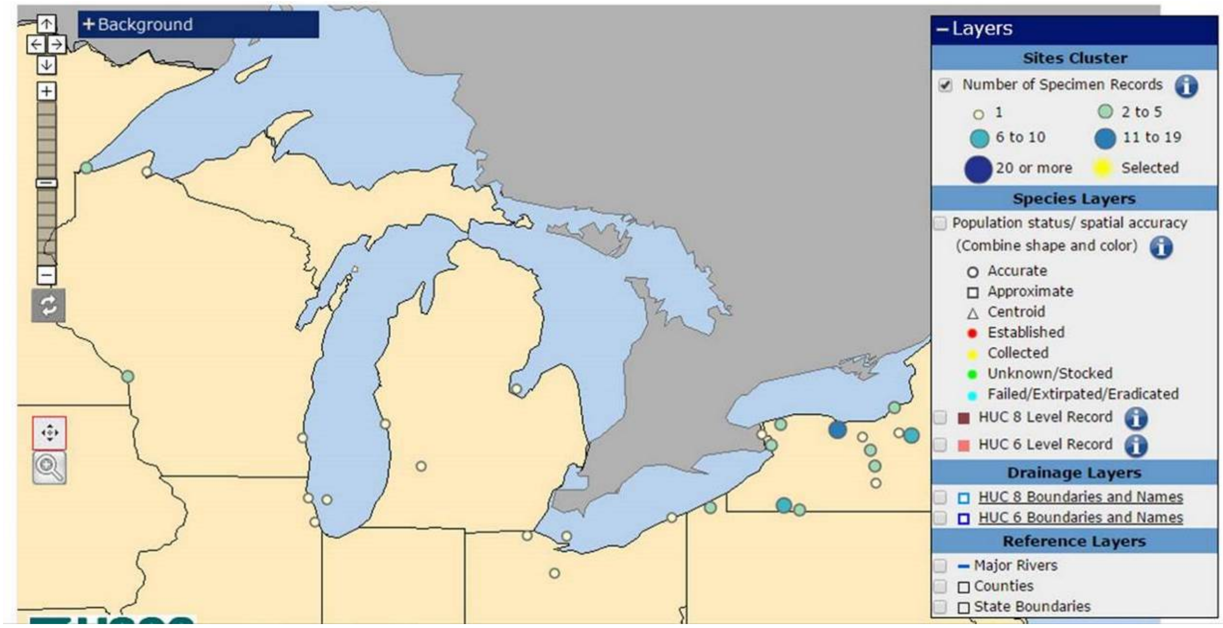

Figure 6. Locations of *Bithynia tentaculata* in USGS NAS website PRIOR to our project providing additional locations where they were collected.

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

In collaboration with the Great Lakes Environmental Indicators project and researchers at the USEPA Mid-Continent Ecology Division in Duluth and at the University of Wisconsin Superior, a note was published in the Journal of Great Lakes Research about the spread of *Bithynia* in Lake Superior (Trebitz et al. 2015). A second publication focusing on the factors that may contribute to *Bithynia* invasion, authored by CWMP scientists, is currently in review for publication.

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

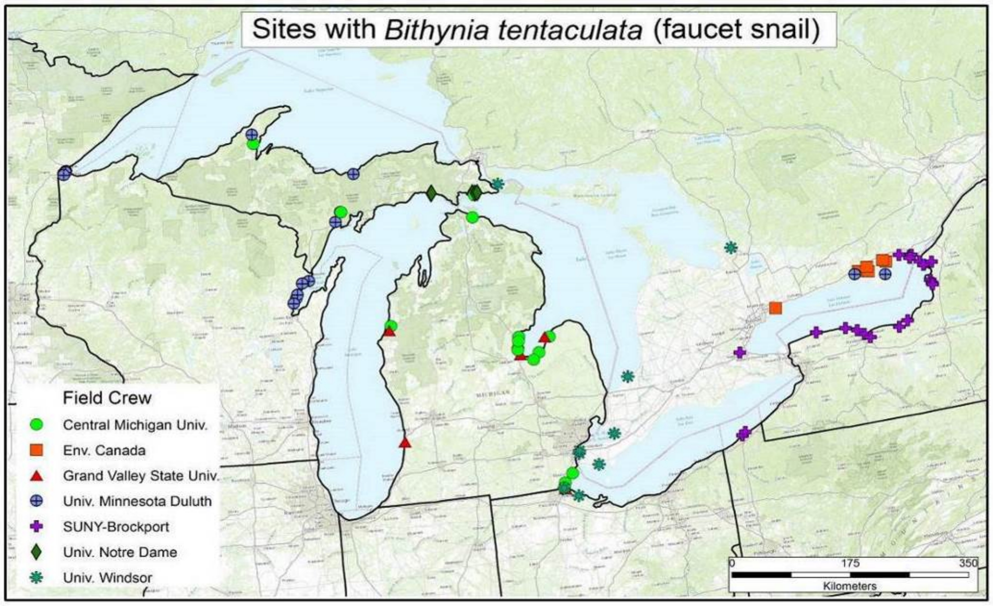

Figure 7. Locations of *Bithynia tentaculata* found by CWM crews, 2011 - 2013.

On average, there were approximately 42 wetland plant (macrophyte) species per wetland (Table 13), 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 13). 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 keep restored wetland sites from becoming dominated by invasive plant species.

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

Table 13. 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 and this information is out-of-date. We are in the process of updating these designations for wetland macrophytes. At-risk species (federal and state-designated) were not commonly encountered during sampling through 2015, as can be seen in Table 13. 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 14). Maximum species richness in Lake Erie wetlands was lower than wetlands on the other Great Lakes. 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 14. 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.

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.

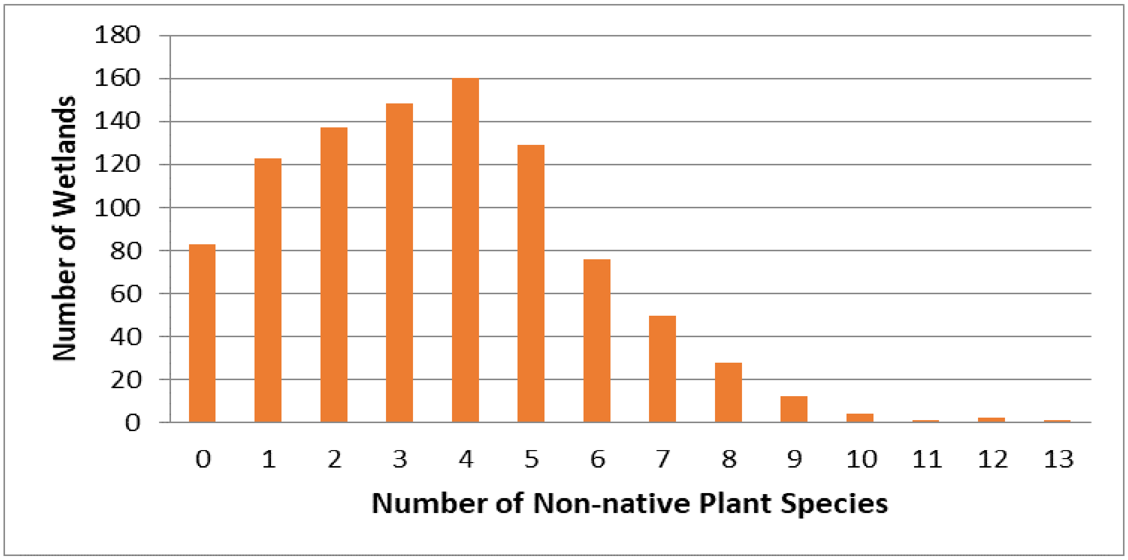

Figure 9. Number of Great Lakes coastal wetlands containing invasive plant species based on 2011 through 2018 data.

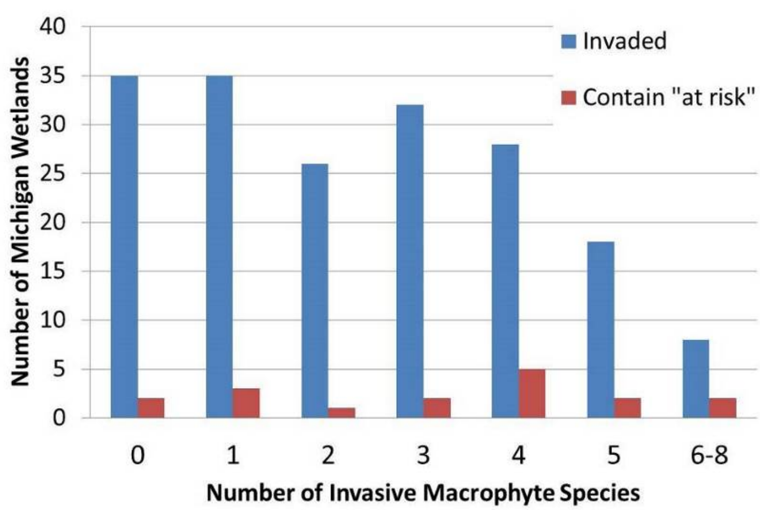

Figure 10. Number of state of Michigan Great Lakes coastal wetlands containing both invasive plant species and “at risk” plant species, based on 2011 through 2014 data.

We created a map of invasion status of Great Lakes coastal wetlands using all invasive species data we collected through 2014 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.

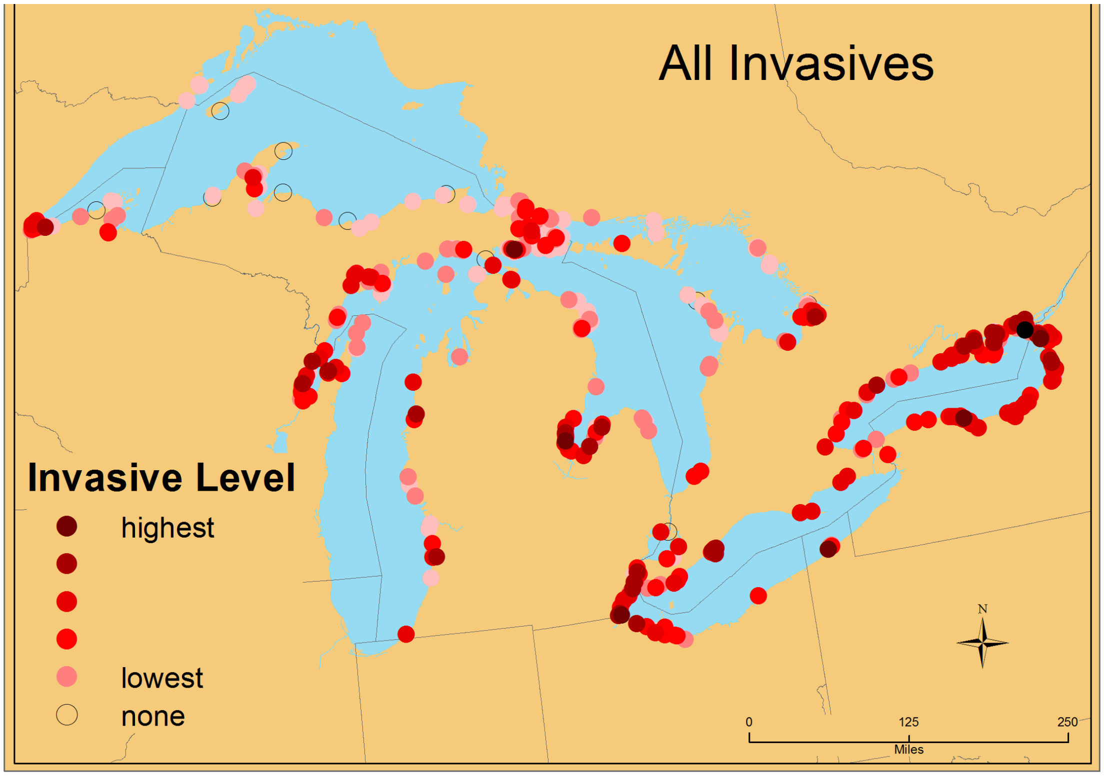

Figure 11. Level of "invadedness" of Great Lakes coastal wetlands for all non-native taxa combined across all taxonomic groups, based on data from 2011-2014.

Wetland Condition

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

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

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

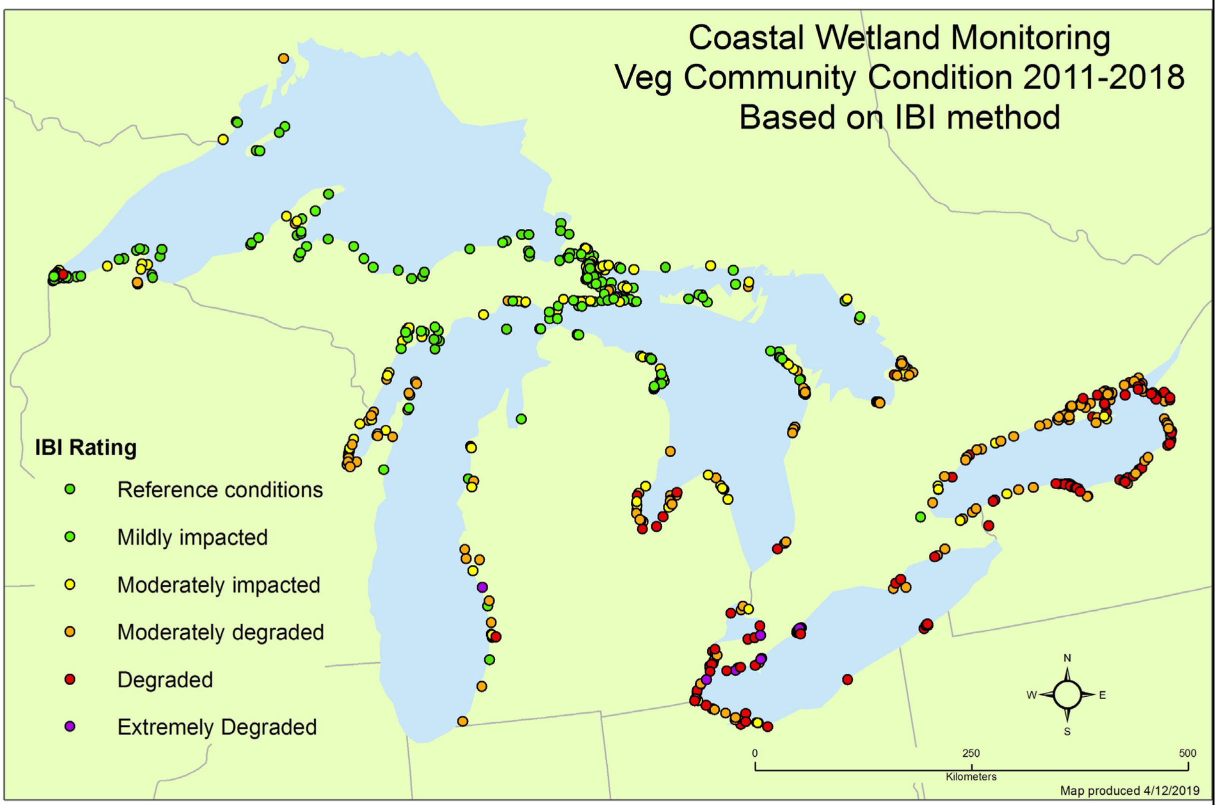

Figure 12. Condition of coastal wetland vegetation at sites across the Great Lakes. Circle color indicates vegetation community quality. The indicator is labeled “draft” while this indicator is investigated for robustness against varying water levels and latitude. Based on data from 2011 through 2018.

concentrated in the southern Great Lakes, where there are large amounts of both agriculture and urban development, and where water levels may be more tightly regulated (e.g., Lake Ontario), while sites with high FQI scores are concentrated in the northern Great Lakes. Even in the north, an urban area like Duluth, MN may have high quality wetlands in protected sites and lower quality degraded wetlands in the lower reaches of estuaries (drowned river mouths) where there are legacy effects from the pre-Clean Water Act era, along with nutrient enrichment or heavy siltation from industrial development and/or sewage effluent. Benchmark sites in need of restoration will also have lower condition scores. Note that this IBI has been updated and adjusted since the start of the project, accounting for the shift in condition scores for a handful of sites. This adjustment was necessary to reflect changes in the taxonomic treatment of many marsh plants in the 2012 Michigan Flora and Flora of North America.

Another of the IBIs that was developed by the Great Lakes Coastal Wetlands Consortium uses the aquatic macroinvertebrates found in several of the most common vegetation types in Great Lakes coastal wetlands: sparse bulrush (*Schoenoplectus*), dense bulrush (*Schoenoplectus*), and wet meadow (multi-species) zones. We have calculated these IBIs for sites sampled from 2011 through 2018 that contain these habitat zones (Figure 13). 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.

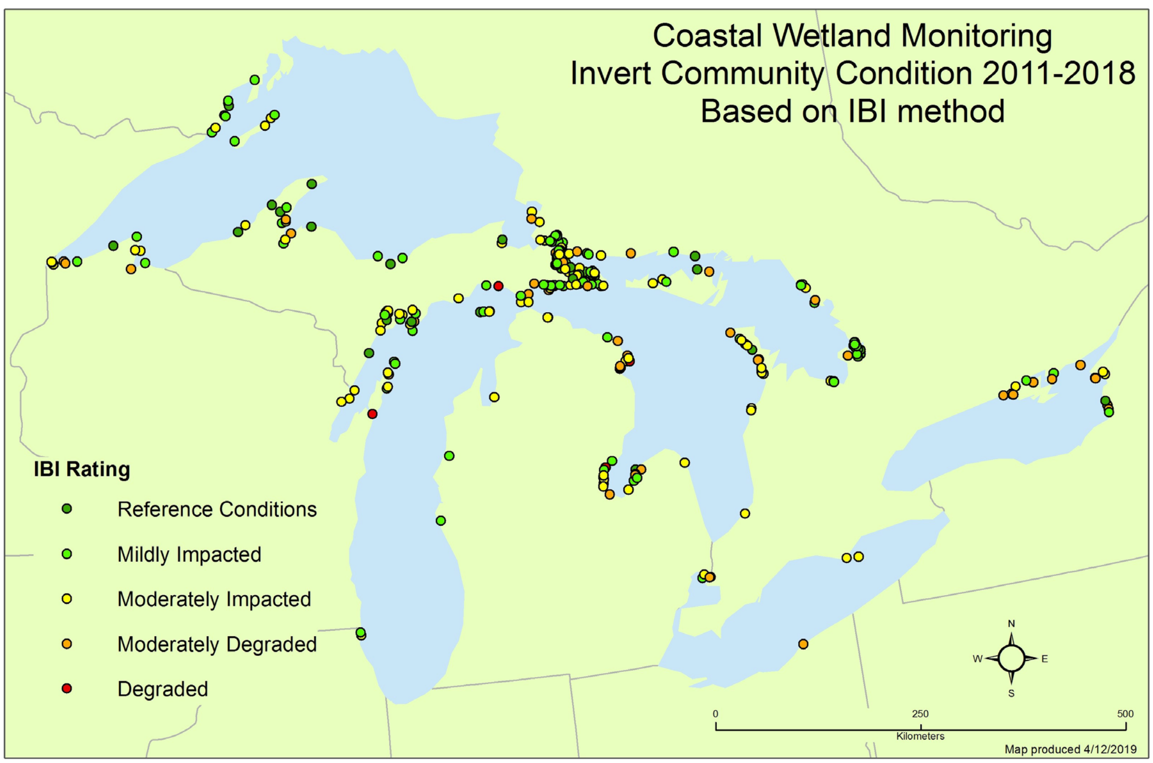

Figure 13. Condition of coastal wetland macroinvertebrate communties at sites with bulrush or wet meadow zones. Based on data from 2011 through 2018.

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, but these 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.

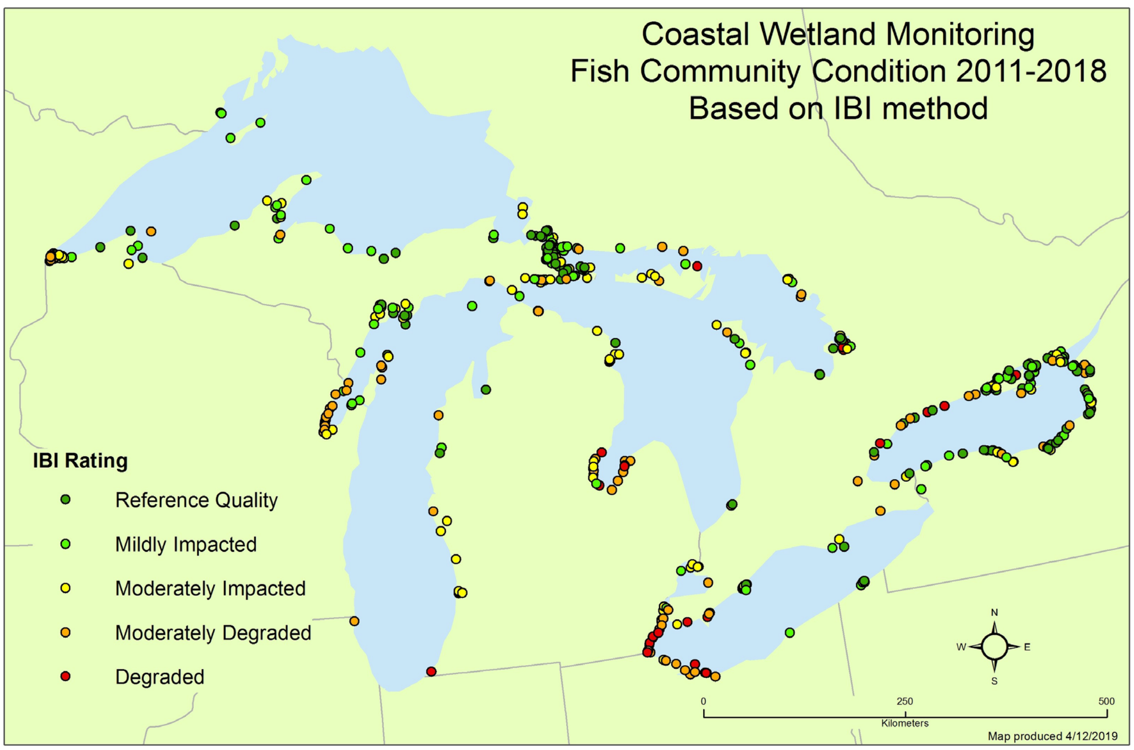

Figure 14. Condition of coastal wetland fish communties at sites with bulrush, cattail, lily, or submerged aquatic vegetation zones. Based on data from 2011 through 2018.

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 the Great Lakes Ecological Indicator (GLEI) project (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 GLEI 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.

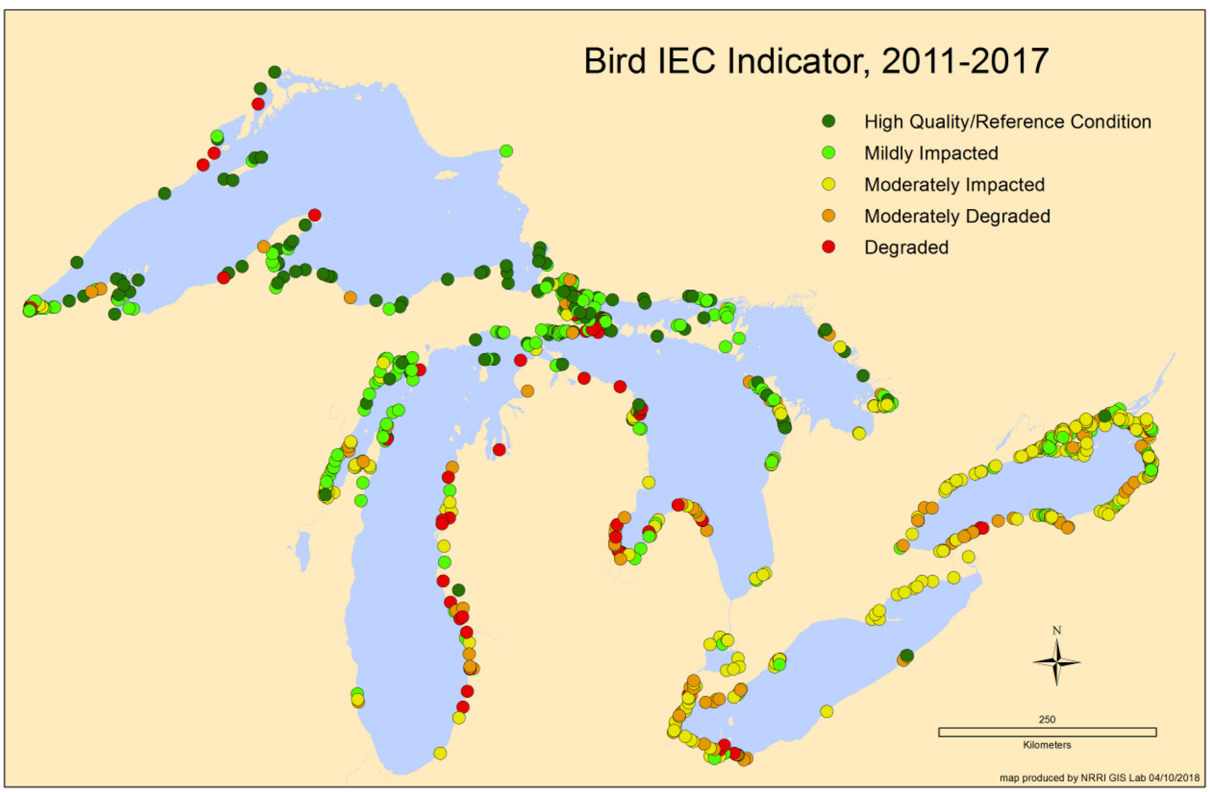

Figure 15. Condition of coastal wetland bird communties. This indicator is based on the IEC method using data from 2011 through 2017.

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 15). 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 15. 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 16), 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 ($p = 0.20$).

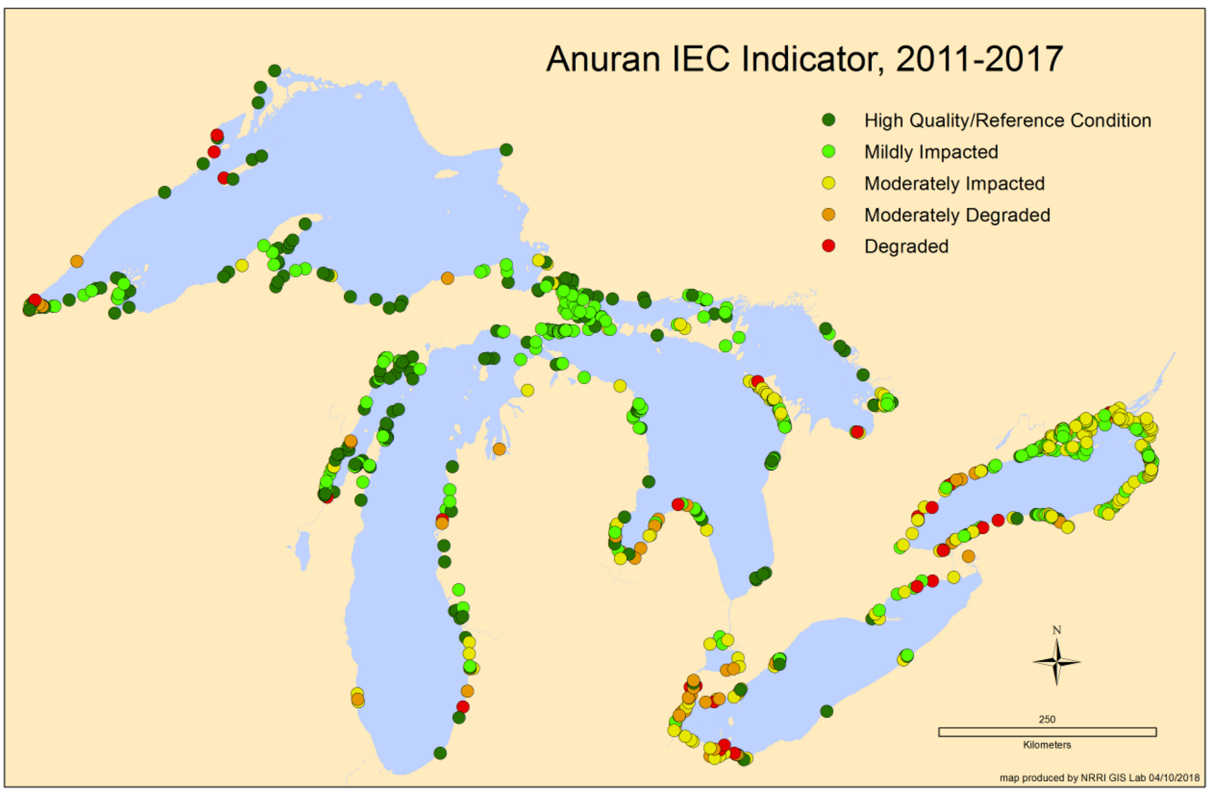

Figure 16. Condition of coastal wetland calling anuran communties. This indicator is based on the IEC method using data from 2011 through 2017.

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 $\overline{x}$ = 3.14, SE = 0.11; high water $\overline{x}$ = 3.72, SE = 0.13), Lake Michigan (low water $\overline{x}$ = 3.53, SE = 0.10; high water $\overline{x}$ = 3.85, SE = 0.12), and Lake Huron (low water $\overline{x}$ = 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 16. 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)

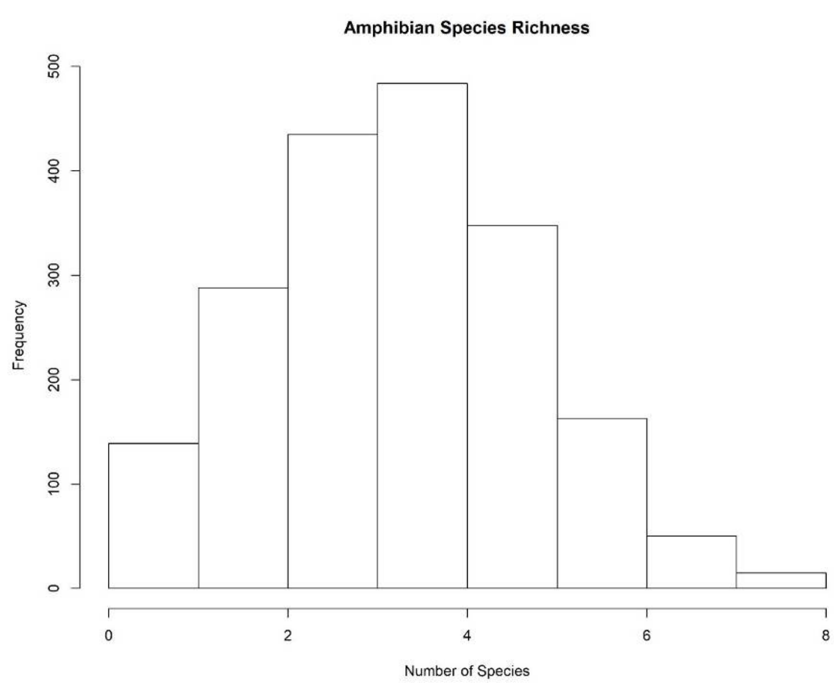

Figure 17. Distribution of species richness at coastal wetland sample points from 2011-2017. Number of species refers to the total number of species recorded during three visits to the point during a given year.

Finally, we have developed a draft disturbance gradient (SumRank) indicator. This indicator is based on landscape stressor data, local stressor data seen at the site itself, and water quality data collected from each aquatic 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 differences in water chemistry associated with the 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 and expect to be able to produce it for the fall report.

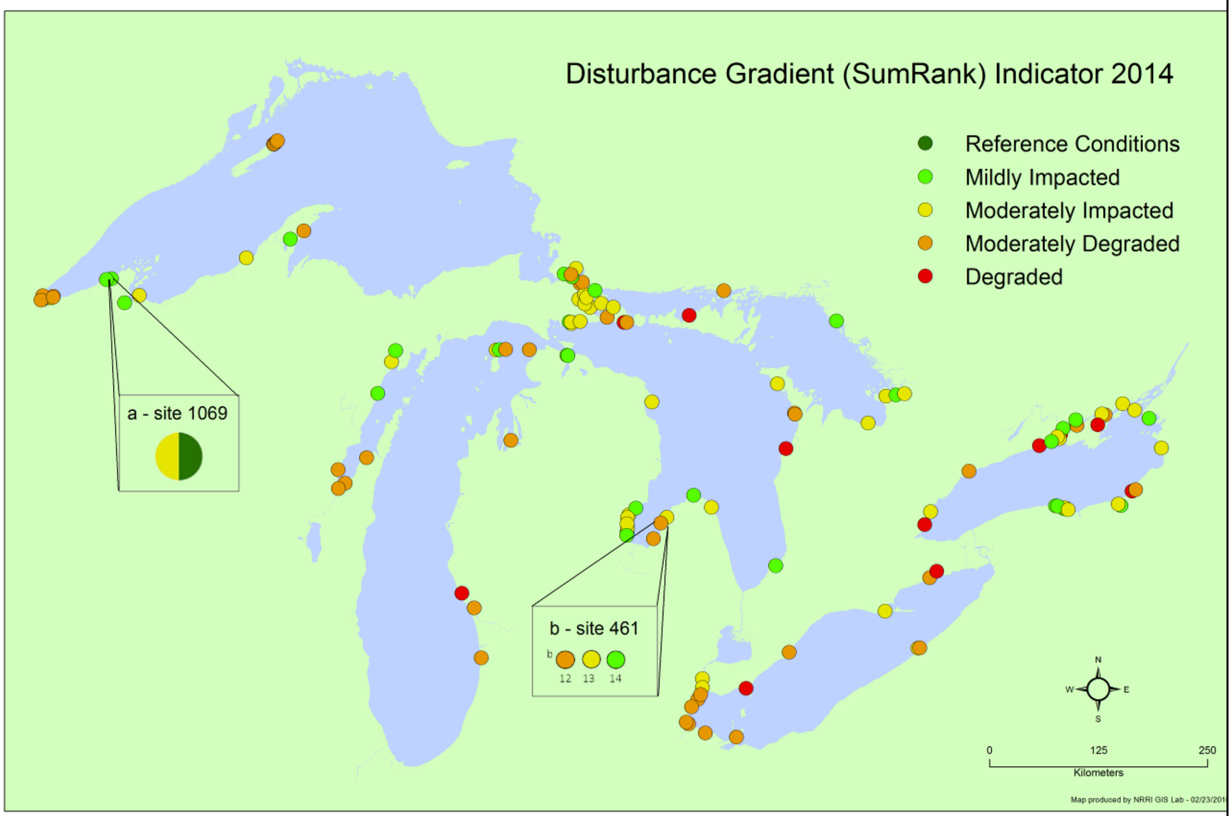

Figure 18. Draft disturbance gradient (SumRank) indicator. This indicator is based on landscape stressor data, site-based stressor data, and site water quality data. This example is based on data from 2014. Wetlands can have different scores for each plant morphotype within them (a), and the indicator may change over time (b).

PUBLIC ACCESS WEBSITE

The Coastal Wetlands Monitoring Program (CWMP) 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, and will modify and enhance the site as required to meet CWMP needs, as well as other end user needs.

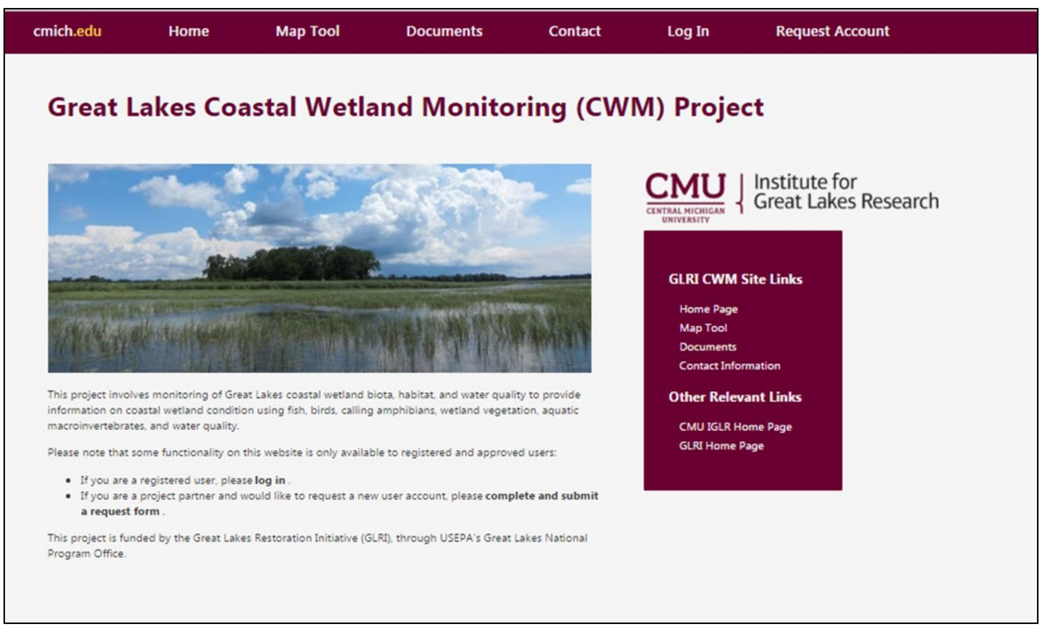

Figure 19. Front page of the re-created Great Lakes Coastal Wetland Monitoring public website, www.greatlakeswetlands.org.

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

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

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

Coastal Wetland Mapping Tool

The enhanced CWMP website provides a new and updated version of the coastal wetland mapping tool described in previous reports (http://www.greatlakeswetlands.org/Map). The basic version of the mapping tool, which is available at the "Public" access level, provides the following features and capabilities (Figure 21):

- Map navigation tools (panning, general zooming, zooming to a specific site etc.);
- Basemap layer control (selection of aerial vs. "ocean" basemaps);
- Display of centroids and polygons representing coastal wetlands that have been monitored thus far under the CWMP;
- Capability to style/symbolize wetland centroids based on: 1) geomorphic type (default view; Figure 21), or 2) year sampled (Figure 22); and

- Reporting of basic site attributes (site name, geomorphic type, latitude, longitude, and sampling years).

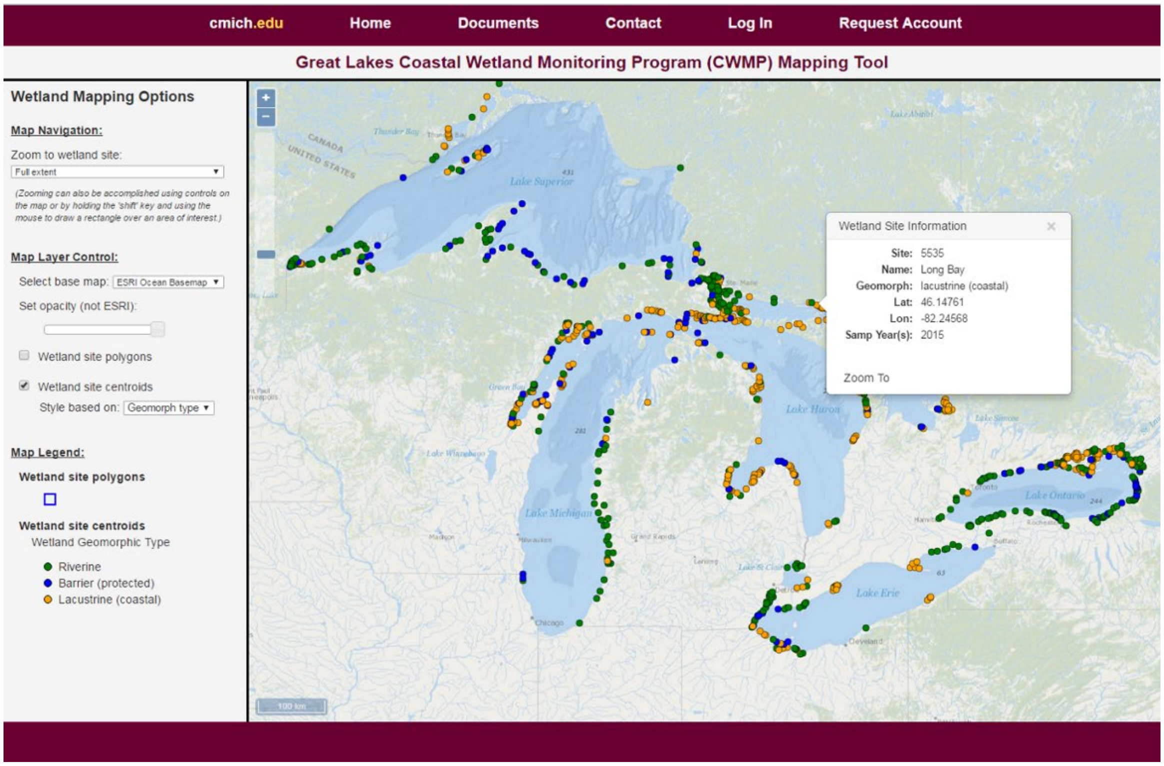

Figure 21. Coastal Wetland Mapping Tool – Public Version (geomorphic type view).

In addition to the features made available at the “Public” access level, users with “Level 1” access to the website can currently obtain information regarding IBI scores for vegetation, invertebrates, and fish. (IBI scores for amphibians and birds are now being added to the site).

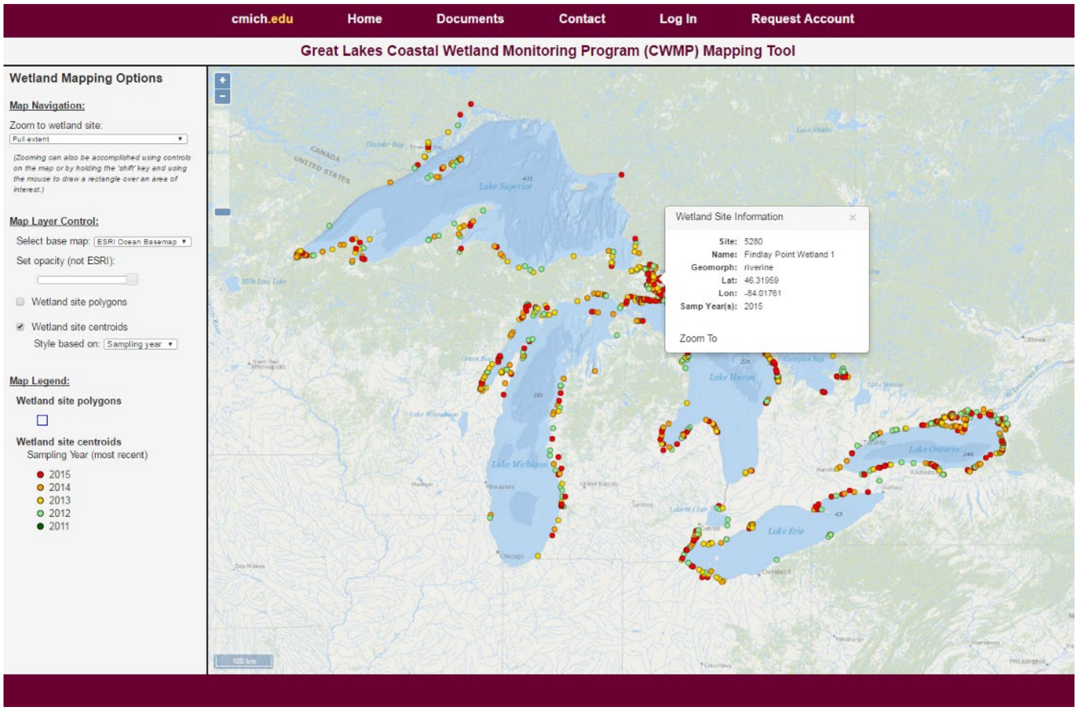

Figure 22. Coastal Wetland Mapping Tool – Public Version (sampling year view)

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.

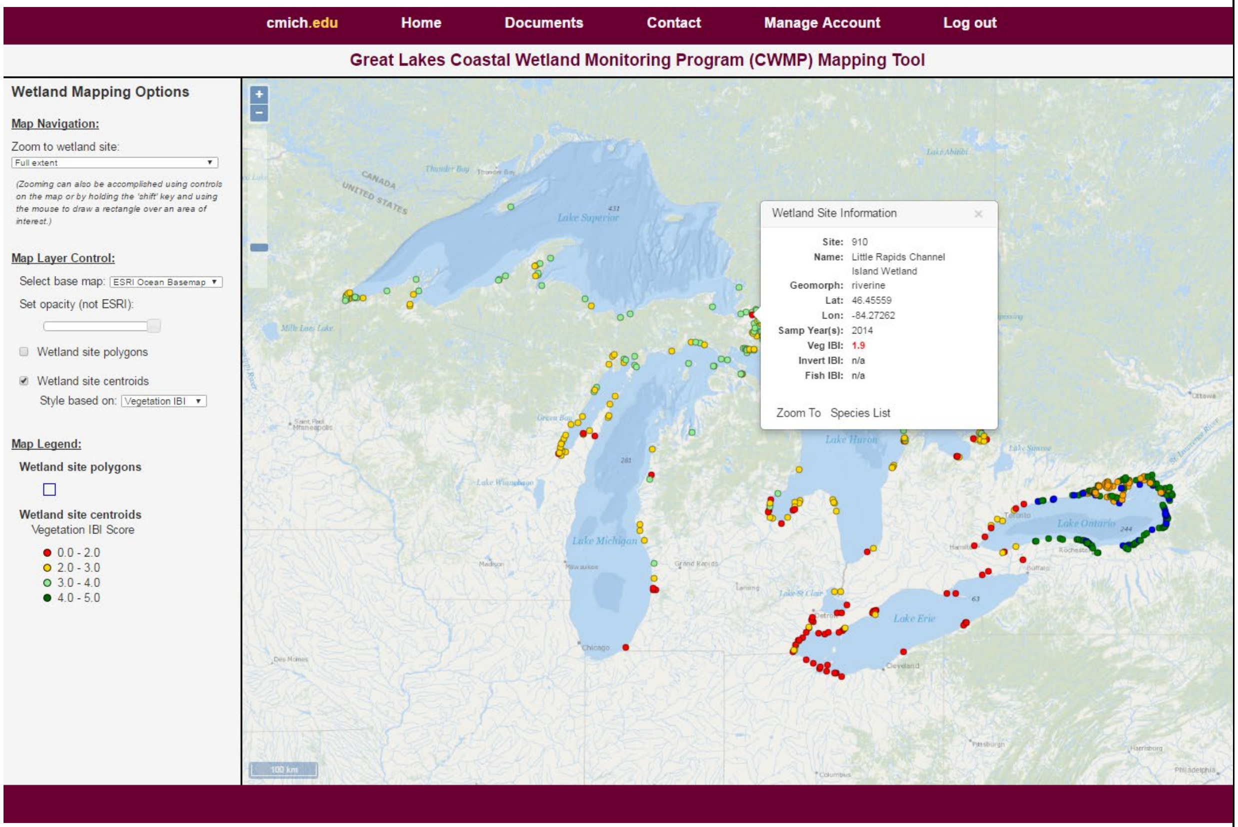

Figure 23. Coastal Wetland Mapping Tool with IBI scores displayed.

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

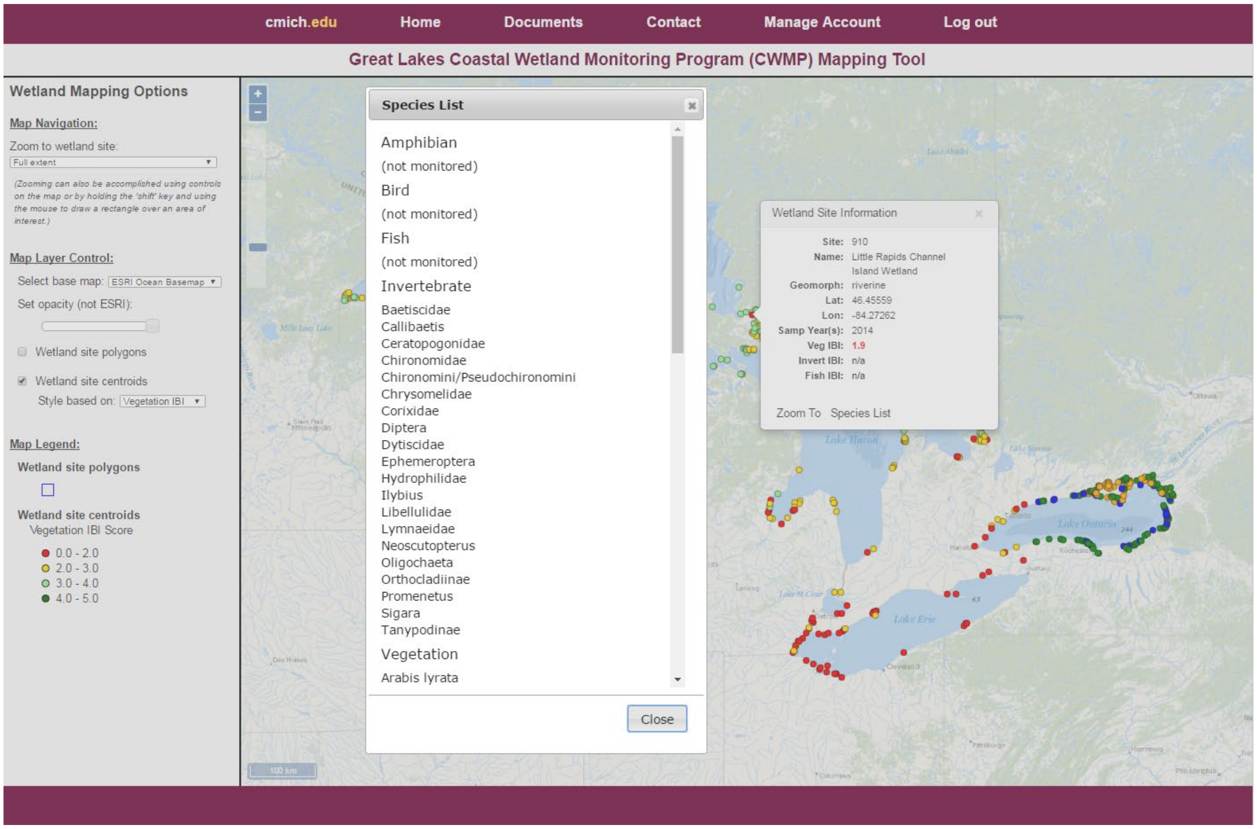

Figure 24. Coastal Wetland Mapping Tool with wetland macrophyte IBI scores and species list.

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 program 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 such as water levels or local issues can affect the samples, they had a better understanding of how to interpret the results and of the limitations of this information. Many people were supportive of website improvements to provide more of this information to users online, and they were excited to hear about the decision support tool, currently under development.

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

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

TEAM REPORTS

WESTERN REGIONAL TEAM: Jerry Niemi (Birds and Anurans), Valerie Brady, Josh Dumke (Fish and Macroinvertebrates), Nicholas Danz (Vegetation), and Rich Axler (Water Quality)

2018 Sample Processing, Data Entry, and QC

All 2018 bird, anuran, fish, vegetation, habitat, and field and lab water quality data have been entered into the database and QC'd. Blinded macroinvertebrate samples were exchanged between NRRI and Lake Superior State University for QC of invertebrate identification. Fish, invertebrate, vegetation, habitat and water quality data were subject to QA/QC procedures by visually checking every data entry field in the data management system against the field sheets. Errors were corrected in the database and noted on field sheets. Error rates remain very low.

Results from 2018

Birds and anurans:
The Western Regional Team has conducted a review of the entire anuran and bird datasets. A number of data quality issues ranging from errors in dates to mismatches in GPS locations and missing data have been or are being resolved.

Fish and macroinvertebrates:
Water levels remained high in Lake Michigan compared to the early years of this project (through 2015). The NRRI field crew encountered zones too deep to fish (e.g. SAV), and fished zone types that typically were too shallow in the past (e.g. wet meadow). We now even

encounter cattail zones that can be too deep for our fyke nets. The water level in Lake Superior wetlands was not noticeably different from prior years.

During summer of 2018 the NRRI field team visited 23 coastal wetlands in lakes Superior (11 wetlands) and Michigan (12 wetlands). Overall, 41 vegetation zones were sampled for invertebrates, and 31 vegetation zones were sampled for fish. Wetlands were classified as barrier (n=4), lacustrine (n=9), and riverine (n=10). Five sites were designated as benchmark sites, four were re-samples, and two sites were considered “pre-sample” sites that will be temporal resample sites this year. We sampled a site in Green Bay scheduled for restoration in 2019 or 2020. This site (1444) had a lot of public litter which likely originated from a nearby highway overpass. The fish community was largely comprised of species adapted to degraded habitats and low oxygen such as bullheads, common carp, central mudminnow, and bowfin (Figure 25). Data gathered at these “pre-restoration” sites will be important to determine future change at these wetlands following the completion of restoration projects.

Figure 25. Field technician Matt Santo of NRRI holds a Bowfin displaying green breeding colors. Photo taken at site 1444 on 6/30/18.

Invertebrate samples collected in 2018 (n=123) were identified, QC’d, and entered into the GLCWMP database by the end of March, 2019. NRRI laboratory technicians identified 17,647 organisms, so each replicate contained on average 143 invertebrates. Isopods and amphipods comprised about half of the macroinvertebrates identified from *Typha*, Wet Meadow, SAV, and *Phragmites* vegetation zones. A short spikerush vegetation zone at site 1051 (Stockton Island) was dominated by mites (*Acari*), which comprised nearly 68% of all invertebrates collected within that vegetation type. Invasive faucet snails (*Bithynia tentaculata*) were collected at 7 sites among SAV, Sparse Bulrush, Lily, *Phragmites,* and *Typha* zones. Eight times as many faucet snail were collected in 2018 than 2017 (302 and 35, respectively). Invasive Zebra Mussel (*Dreissena polymorpha*) were collected at four sites among *Typha*, SAV, and Sparse Bulrush zones (n=13 in total). Percent of sensitive wetland orders Ephemeroptera, Trichoptera, and Odonata (ETO) were low among all vegetation zones that our team sampled, particularly in *Phragmites* zones at 1.7% of total invertebrate composition.

Several game species of fishes were present as young-of-year (YOY), which indicates adults had used nearby wetland habitats to reproduce. Game fish observed as YOY were Walleye, Northern Pike, Smallmouth Bass, Largemouth Bass, Yellow Perch, and Black Crappie. Walleye YOY were only captured at two sites in the greater Green Bay area. We also continue our data collection of gar species distribution. 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 (Figure 26), even though there is no physical barrier separating the two populations.

Figure 26. Field teams from NRRI continue to find a range segregation of gar species in the Green Bay, Lake Michigan region. Longnose Gar have only been observed in the northern extent of Green Bay (TOP; from site 1494), while Longnose x Shortnose Gar hybrids populate the southern extent of Green Bay (BOTTOM; from site 1465).

Painted turtles were common by-catch, but we did not encounter any Common Snapping Turtles in 2018 (which is atypical). We did not encounter any fish of threatened, endangered, or special concern status during our 2018 field sampling. However, we did observe several invasive species. Invasive fish were present at 14 of the 19 fished sites. Round Goby and Common Carp were the most frequently detected, although their prevalence was greater in Lake Michigan wetlands than Lake Superior. Other invasive fish observed were Alewife, Ruffe, Rainbow Smelt, and Tubenose Goby. Non-native Three-spine Stickleback were observed at one Canadian site (5963: Sturgeon Bay Wetland 1). The NRRI crew collected rusty crayfish within one Lake Superior wetland (1074) and two Lake Michigan wetlands (1441 and 1687).

Some interesting observations occurred at site 1051 (Presque Isle Pointe Wetland). The fish community in this lagoon on Stockton Island in the Apostle Islands area of Wisconsin appears very productive. We caught hundreds of brown bullheads as well as many cyprinids and a few centrarchids. However, this is the second time we have caught very few aquatic macroinvertebrates in this wetland. We suspect some top-down control of the macroinvertebrate food web or some other interesting mechanism driving this pattern. This wetland is considered a "poor fen" and has a well-developed floating peat mat throughout. Coastal Wetland Monitoring data are being used to place Apostle Islands wetlands into a broader Great Lakes context.

Aquatic macrophytes:
We encountered a few notable species that had not been observed by our team in years prior to 2018:

- *Salix serrisima*, with Coefficient of Conservatism (C) of 8 was found at one site in the St. Louis River estuary. This species has only been reported a few times from the estuary region.
- *Carex lurida* (C=3) apparently previously uncollected from eastern Wisconsin, was noted at Quarry Point Area Wetland (site 1687) on the Door Peninsula of Wisconsin.
- *Carex michauxiana* (C=10) was noted from Site 1027 on the Firesteel River in the western Upper Peninsula of Michigan.
- *Rhynchospora capitellata* (C=6) was noted from Site 1494 in the Rapid River Wetland complex, Michigan.

Additionally, although we found no new invasive species among the sites in our region, several sites were heavily infested with Eurasian Water-milfoil, including:

- Site 1438 Henderson Point Wetland, Site 1441 Point Au Sable, and Site 1687 Quarry Point Area Wetland, on the Door Peninsula, WI
- Site 1465 Pensaukee River wetland and Site 1703 Seagull Bar Area wetland along the west shore of Green Bay in WI, and
- Site 1489 Escanaba River wetland in the Upper Peninsula of Michigan.

Throughout the past year, we have also been working to develop statistical models that appropriately estimate both annual status values as well as temporal trends. We have used one indicator of vegetation quality, Mean C, as the response variable (Figure 27). We collaborated with a professional statistician to develop computing code that would consider all aspects of the serially repeating, augmented rotating panel design. Although this work is in draft stages, we generally observed higher Mean C values in the first few years, followed by a few years of lower values, and a return of higher values in recent years. We are investigating how these fluctuations may be linked with recent changes in lake water levels. Statistically, trends of Mean C were non-significantly different from zero for Lakes Superior, Michigan, Huron, and Ontario, whereas for Lake Erie, we noted a significantly increasing trend in Mean C over the course of the project.

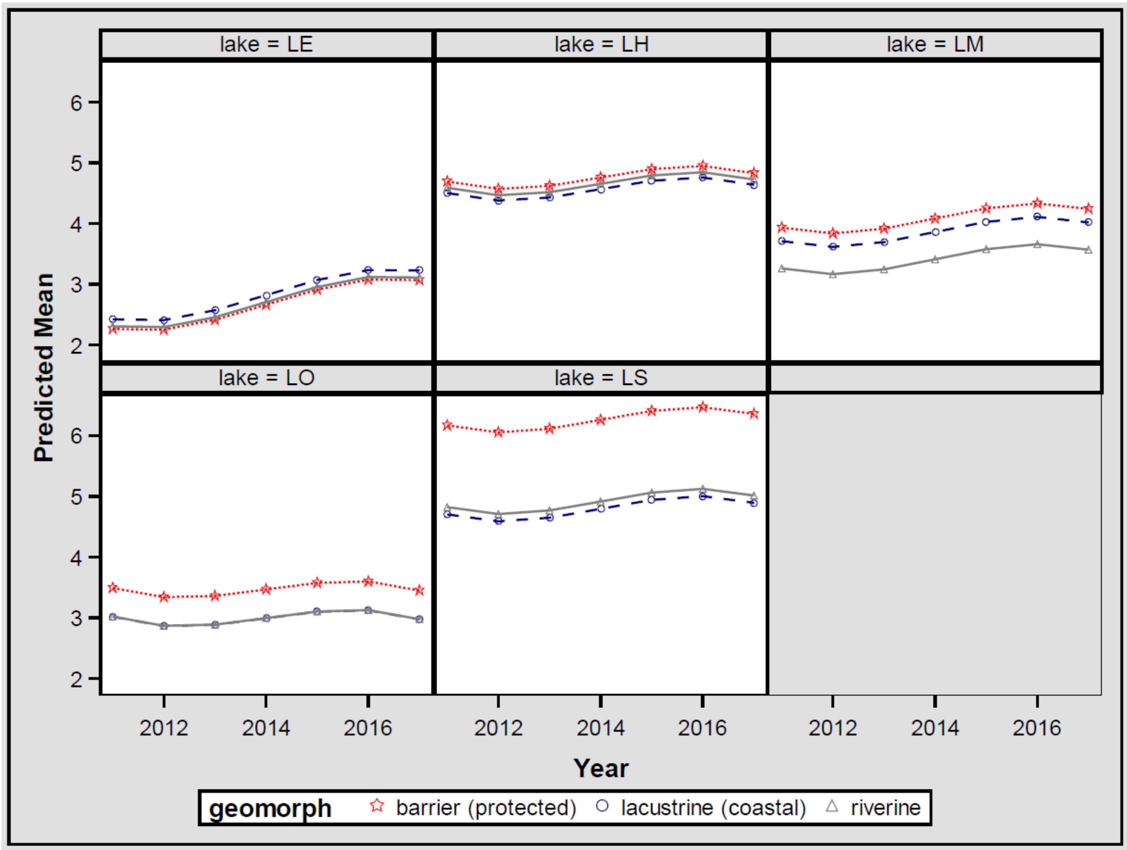

Figure 27. Predicted annual Mean C values from statistical estimation considering aspects of the rotating panel design. The trend for Lake Erie represents a significant increase (positive trend) over the time period, whereas other trends were not statistically increasing nor decreasing.

Leveraged benefits

<u>Restoration Activities in the Western Great Lakes:</u>
Western team bird PIs (Niemi, Bracey) have been participating on the technical teams associated with wildlife, habitat, and Beneficial Use Impairment (BUI) issues associated with the St. Louis River Area of Concern. The most recent activity involved recommendations on the removal objective and restoration of Interstate Island to benefit the Common Tern. The Common Tern is a *threatened* species in Minnesota and *endangered* in Wisconsin, and restoration of Interstate Island is critical for the recovery of that species population in the St. Louis River system. We are currently part of the design team, headed by Minnesota Land Trust, working with other state, federal, and local organizations to provide information about habitat

preferences of waterbird and shorebird species that will benefit long-term from restoration of the island. Restoration is scheduled to begin in late-summer of 2019. We are also working with National Audubon to help them identify locations in the estuary to prioritize for restoration activities based, in part, on avian data collected at benchmark sites throughout the estuary.

Similarly, agencies leading the clean-up and restoration of the St. Louis River Area of Concern, particularly the Minnesota Pollution Control Agency and the Wisconsin Department of Natural Resources, continue to request sampling and data on wetland plants, macroinvertebrates, water quality and fish for specific estuary wetlands before and after clean-up or restoration work. Because there are a couple of dozen wetlands in this estuary, PIs Brady and Danz are kept busy managing these requests.

Coordination and Potential Partnership with National Audubon: The CWM bird PIs continue to work with the National Audubon science team. There has continued to be turnover of their team handling the CWM bird data. We met with Nathaniel Miller, Stephanie Beilke, and Sarah Saunders of National Audubon-Great Lakes to discuss their continued work with CWM bird data for the Great Lakes. The CWM representatives included CWM PIs Gerald Niemi, Bob Howe, and Doug Tozer and graduate students Lisa Elliott, Tara Hohman, and Lisa Broullette. The focus of the discussion included the following:

1) Audubon is interested in trying to participate in our monitoring to include volunteers but we primarily steered them to potentially having them volunteer for the Marsh Monitoring Program - at least for those that are qualified. We noted that we have a rather rigid protocol and it is not very amenable given the strict experimental design we have.
2) Audubon is concentrating on the use of our data for an update on their climate models for North America which this time will include land cover in addition to the climate envelope approach they previously used. We were impressed with their modelling expertise and I think they will have a fine product. We were impressed with the previous version and the next iteration is projected to be delivered sometime next summer.
3) Audubon has also begun to focus on gathering extensive breeding bird data with volunteers (point counts) at sites where they working on restoration. They presented some results for the Calumet area in Illinois/Indiana. It was impressive and should be encouraged. They are also planning future activity in the Duluth-Superior area in MN and WI and in Green Bay, WI – Bracey and Niemi in Duluth-Superior and Howe in Green Bay will collaborate with them in these areas. They are anticipating some activity in the Buffalo and Rochester areas of NY, so this is would be an opportunity for those at SUNY-Brockport to collaborate or at least provide some guidance.
4) Doug Tozer gave a summary of the Great Lakes Marsh Monitoring Program and how it interfaces with the CWM project.

5) Audubon described their work with the CWM data creating a spatial prioritization for wetland protection based on habitat associations of wetland birds and Audubon climate change data.

<u>Modeling of Bird Species of Conservation Concern in the Great Lakes Coastal Region:</u> Lisa Elliott is wrapping up modeling efforts as part of her dissertation 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. She has modeled the distribution of several bird species that are of conservation concern in the Great Lakes and nationally. She has conducted a comparison of habitat associations of these species across different regions using CWM data along with data from the GL Marsh Monitoring Program and the Prairie Pothole Region. She will be defending her dissertation in May 2019.

Here is a summary of her findings thus far:
Secretive marsh birds are notoriously difficult to census because they are both uncommon and cryptic. Thus it is a challenge to identify regionally specific habitat associations, distributions, and population trends for them. To better understand the habitat associations of rare and declining wetland birds in the Great Lakes basin, we are developing six single-species, single season 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. Preliminary results indicate that the probability of detection for Least Bittern (*Ixobrychus exilis*) and American Bittern (*Botaurus lentiginosus*) are influenced by time of day, whereas detection of Pied-billed Grebe (*Podilymbus podiceps*), Virginia Rail (*Rallus limicola*), Sora (*Porzana carolina*), and Common Gallinule (*Gallinula galeata*) is unaffected by the time of surveys. Human development is a primary landscape variable negatively influencing the probability of occurrence of American Bittern whereas human population size negatively influences the probability of occurrence of Least Bittern. Resulting models quantify species-specific habitat associations and will provide basin-wide predictive models on the distribution of rare, obligate coastal wetland birds to prioritize areas for conservation or potential restoration.

<u>Population Modeling and Mercury Exposure of Common Terns in Western Lake Superior:</u> Annie Bracey is completing modeling efforts as part of her dissertation in the Conservation Sciences Ph.D program at the University of Minnesota, Twin Cities. Dr. Niemi is co-advising Bracey along with Dr. Francesca Cuthbert. She is modeling the population dynamics of Lake Superior Common Tern colonies using Integrated Population Models and is determining mercury exposure based on foraging habitat using GPS tracking and stable isotope analyses. She has also been involved in a collaborative effort to track Common Terns throughout the year in the Great Lakes region using light-level geolocators and was the lead author on the following publication of those efforts: Bracey, A., Lisovski, S., Moore, D., McKellar, A., Craig, E., Matteson, S., . . . Cuthbert, F. (2018). Migratory routes and wintering locations of declining inland North

American Common Terns. *The Auk, 135*, 16. doi: 10.1642/AUK-17-210.1**)**. Annie will be defending her dissertation in May 2020.

Assistance to Lake Superior National Estuary Research Reserve: We aided Hannah Ramage from the Lake Superior National Estuarine Research Reserve (LSNERR) in a very specific and localized request to learn where invasive Tubenose Goby were detected within the St. Louis River Estuary. Information about the Reserve, including their mission statement, can be found at https://lakesuperiorreserve.org/

Assistance to the US Fish and Wildlife Service, Green Bay: Joseph Sheahan of the Fish and Wildlife Service in Green Bay, WI asked for 2018 Northern Pike data in the greater Green Bay area to help his team evaluate completed or ongoing habitat projects.

Field Training

Birds and Anurans:
Training for anuran surveys will be held on 22 April 2019 and bird crew training will take place 16 May 2019. Training involves instructing crews on how to conduct standardized field surveys, on basic travel procedures, and on appropriate field safety measures. Individuals are trained to proficiently complete field sheets and audio testing is also completed to insure that their hearing is within the normal range. Rules for site verification, safety issues including caution regarding insects (e.g., Lyme's disease), GPS and compass use, and record keeping are also included in field training to insure that the guidelines in the QAPP are being followed. All individuals involved in conducting the surveys in 2019 will have taken and passed each of the following tests on 1) amphibian calls, 2) bird vocalization, and 3) bird visual identification that are based on an on-line system established at the University of Wisconsin, Green Bay, prior to conducting surveys – see http://www.birdercertification.org/GreatLakesCoastal.

All new and returning field observers will review the QAPP and SOPs and complete the online certification requirements (see above) prior to conducting field surveys. The supervising PI will conduct mid-season checks by visiting survey locations and verifying that proper protocol is being implemented. All data entry and QA for bird and amphibian records will be completed (100%) by September 2019.

Fish, Macroinvertebrates, Vegetation, and Water Quality:
Fish, macroinvertebrate, vegetation, and water quality sampling training will be held in Duluth, Minnesota, and Superior, Wisconsin, in mid-June 2019 and will continue in Green Bay, Wisconsin at the end of June/early July. All field technicians will be trained in and tested on all standard procedures, including a field-based fish or vegetation identification exam (depending on the crew). Training includes how to determine if a site meets project criteria, all aspects of sampling the site, proper recording of data on datasheets, GPS use and uploading, water quality sample collection and meter calibration (fish/invert crew only), as well as sample processing.

Much of the training takes place in the field at a typical coastal site to ensure field members learn (or review) appropriate techniques. Safety training covered aspects of field safety including safe boating; protection against the elements, animals, insects, and plants; and what to do when things go wrong. A CPR/AED and first aid review class will also be offered to fish/invert crew members.

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

Site selection

Birds and Anurans:
In 2019, a total of 51 sites have been selected to be surveyed by the western regional team for birds and anurans. Of these sites, 49 have been selected for sampling in previous years of this Coastal Wetland Monitoring program. Three new benchmark sites were added this year for pre-restoration sampling, resulting in a total of 14 benchmark sites. Twelve benchmark sites are located in the St. Louis River Estuary and are in some stage of planning for restoration work. Restoration activities for the sites are being coordinated by the Minnesota Pollution Control Agency and the US Fish and Wildlife Service, with many collaborators from multiple agencies and university research groups. All of the sites selected for sampling were reviewed to determine whether they were deemed safe and accessible to field crews. Twelve sites were web rejected because of safety and accessibility issues (these sites also could not be sampled in previous years of the Coastal Wetland Monitoring program), and five of the benchmark wetlands in the St. Louis River Estuary that must be accessed by boat will only be surveyed for birds because of the safety concerns specific to nighttime anuran surveys.

The sites that will be sampled in 2019 by bird and anuran field crews stretch from the Duluth-Superior harbor area and along Minnesota's north shore of Lake Superior, eastward along the south shore to the eastern end of the Upper Peninsula of Michigan and into northeastern Lake Huron. In 2019, several island sites are also scheduled to be sampled, including five sites in the St. Louis River Estuary, and seven sites in Ontario (Manitoulin Island, St. Joseph Island).

Fish, Macroinvertebrates, Vegetation and Water Quality:
NRRI was initially assigned fewer sites than we have capacity for, while our neighboring central basin crews were assigned more sites than they have capacity. We will sample about half a dozen sites originally assigned to Central Basin crews. Thus the NRRI team will sample 26 wetlands in 2019. Ten wetlands are in the Lake Michigan basin, and 16 are within the Lake Superior basin. Nine of those sites are Benchmarks in both the St. Louis River and Green Bay AOCs, three are re-samples, and two sites are designated as pre-samples for temporal resampling next summer.

Field sampling plans

Birds and Anurans:
Each of the 39 coastal wetland sites will be visited a total of four times between 1 April and 15 July 2018 (exceptions being the five boat-access sites not visited for anurans—these sites will be visited twice for birds only). Anurans will be sampled three times at dusk during this period and birds will be surveyed twice, once in the morning and once in the evening.

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

Central Basin Regional Team: **Don Uzarski, Dennis Albert (Vegetation), Thomas Gehring and Robert Howe (Birds and Anurans), Carl Ruetz, Ashley Moerke, and Gary Lamberti (Fish and Macroinvertebrates)**

Sample Processing and Data Entry (2018)

Central Michigan University:
From October 1st, 2018 through March 31st, 2019, lab analyses and data entry were completed and checked following QA/QC procedures for water quality, habitat, macroinvertebrates, and fish. Invertebrate samples were exchanged with GVSU for cross lab QA/QC, which was completed in late March. All inconsistences between sample identifications were discussed and taxonomists agreed on how to identify these groups correctly moving forward. Any past identification of these groups that may be incorrect will be checked. In early March, database waypoint errors were reported to all PIs by Todd Redder for sites sampled in 2011-2018.

PI Dennis Albert has completed the identifications of all unknown pressed plant samples collected in 2018. All 2018 plant data has been entered into the database and has been checked. Additionally, Dr. Albert has performed a final check on all 2018 data. Upon review of 2018 data, Dr. Albert noted that there was a 400 to 1000% increase in coverage of invasive *Hydrocharis morsus-ranae* (invasive European frog bit) at 3 sites and two new sites where it had not previously been noted. Increases were noted at Halfway Creek on Lake Erie, at Raber Bay and Munuscong Island on the St. Marys River. The new sites were Linwood and E. Saginaw Bay #2 on Saginaw Bay.

100% of 2018 field data have been entered and checked by a second person. 100% of 2018 macroinvertebrate data have been identified and QC'd. 100% of the laboratory water quality data have been completed and sent to UND and LSSU. CMU water chemistry data have been entered and QC'd. 100% of vegetation samples have been identified and all data have been uploaded to the database and QC'd. All 2017 bird and anuran field survey data have been uploaded and QC'd in the database.

Lake Superior State University:
Data entry for all parameters has been entered and all data except some macroinvertebrates have been checked following the QA/QC procedures. In December, Matt Greib was sent to NRRI to work with Bob Hell and Holly Wellard Kelly for additional macroinvertebrate training and sample checks. For lab exchanges, macroinvertebrate samples were received from NRRI and completed on March 14 and LSSU samples were sent to NRRI for QA/QC at the end of March.

Grand Valley State University:
All field data (i.e., fish, macroinvertebrates, and water quality) were entered and checked for quality control. Identification of the macroinvertebrates collected during the 2017 field season was completed in March 2018 (and those data were entered and checked for quality control in late March 2018). 100% of the 2017 field data has been entered; 100% has been checked by a second person. 100% completion of macroinvertebrate identification for samples collected during the 2017 field season; 100% of 2017 macroinvertebrate data has been entered.

Macroinvertebrate sample exchange and QC with CMU was completed in March 2018. We also completed our annual DNR Collectors Permit reports for fish sampling (for the 2017 field season).

University of Notre Dame:
Field-collected data (fish, habitat, water quality, etc.) and laboratory parameters (water chemistry, chlorophyll-*a*, etc.) have been entered and 100% QC'd. 100% of 2017 macroinvertebrate samples have been identified, entered, and QC'd. Macroinvertebrate sample exchange with UWindsor took place in March 2018 and is expected to be completed shortly.

Analysis of 157 chlorophyll-*a* filter samples from partners [CMU, GVSU, LSSU, UWN, CWS-ON (Environment Canada)] has been completed. Results have been dispersed to all partners. We followed the standard 90% buffered acetone extraction protocol with acidification and then analyzed samples in the dark using a spectrophotometer.

Interesting results from 2018

A CMU postdoc, Anna Harrison, submitted a manuscript to *Wetlands,* describing a Great Lakes basin-wide coastal wetland water quality index (i.e. Sum-Rank). The index uses land use/land cover data and CWMP *in situ* chemical/physical data to assess wetland condition relative to disturbance across different spatial scales and highlights the importance of monitoring water quality in coastal wetlands.

Dr. Albert noted that one rare plant, *Iris lacustris,* was encountered in a wetland in the Straits of Mackinac area. He also notes there is no indication from the plant transects that *Phragmites australis* or other invasive plant coverage has dramatically changed as a result of higher water levels.

2018 Field Season Preparations

Site Selection

Central Michigan University received the 2019 site list and distributed sites among the other central basin crews (University of Notre Dame, Grand Valley State University, and Lake Superior State University). After site trading between the crews, the central basin crew was assigned 52 sites. Three sites were rejected based on oblique imagery or previous knowledge of sites demonstrating lack of connection or sampleable wetland habitat. Ten of the remaining 49 sites were benchmark sites where ongoing restoration is taking (or scheduled to take) place. Of the 49 sites to be sampled in the summer of 2019, 23 were assigned to Central Michigan University, 8 were assigned to the University of Notre Dame, 8 were assigned to Grand Valley State University, and 10 were assigned to Lake Superior State University. Central Basin crews are planning a field training event in early June at a Saginaw Bay site to ensure consistency and competency among crews.

Central Michigan University Aquatic Macrophytes:
Allison Kneisel will lead the 2019 vegetation surveys under the direction of Dr. Albert. Several Central Michigan University students will return for the 2019 sampling season and two new student employees are in the process of being hired. Crew members will be trained in sampling protocol and plant identification in late June of 2019.

After trades, the central basin vegetation crew was assigned 52 sites. Of those, two sites were rejected due to the lack of visible wetlands on the areal imagery, while two other sites were rejected for access issues, leaving 48 sites.

One of the benchmark sites, 619 Duck Bay, which will be sampled in 2019 will provide data to assist wetland remote sensing efforts by a team of Michigan Tech University researchers led by Dr. Laura Bourgeau-Chavez.

CMU Anurans and Birds:
All 2018 field survey data has been uploaded and QC'd in the database. Site selection for 2019 currently includes 50 wetland sites to survey for anurans and birds. These sites are located in northern and eastern Lake Michigan, southern and western Lake Erie, northern Lake St. Clair, and western Lake Huron. Three teams, each with two members, will be used to complete surveys. Field crews will consist of undergraduate student technicians and graduate student crew leaders. Training for anuran surveys was completed at CMU on 11 March 2019. Crew

members have been tested and certified for identification of frog and toad calls and proper field procedures. Anuran surveys will likely begin by early to mid-April 2019, dependent on temperature. Training for bird surveys, procedures, and certification of bird identification will occur in April 2019 prior to sampling.

Lake Superior State University:
Data entry for all parameters has been entered and all data have been checked following the QA/QC procedures. In February, Jesse Wesolek was sent to NRRI for additional macroinvertebrate training and sample checks. For lab exchanges, macroinvertebrate samples were received from NRRI and completed on March 10. LSSU samples were sent to NRRI for QA/QC in February and we are awaiting final ID.

In February, Moerke attended the annual GLCWM meeting in Midland, and announcements were posted for summer crew positions. Interviews were completed at the end of February and hires were finalized in early March. The crew is planning a training session with CMU, GVSU, and Notre Dame in early June to ensure the crews' competency in all parts of the project.

Reporting to the MDNR and Ontario MNR for the scientific collector's permit is underway as is the request for a 2019 scientific collector's permit.

Grand Valley State University:
All field data (i.e., fish, macroinvertebrates, and water quality) were entered and checked for quality control. Identification of the macroinvertebrates collected during the 2018 field season was completed in March 2019 (and those data were entered and checked for quality control in late March 2019). 100% of the 2018 field data have been entered; 100% have been checked by a second person. 100% completion of macroinvertebrate identification for samples collected during the 2018 field season; 100% of 2018 macroinvertebrate data have been entered.

Macroinvertebrate sample exchange and QC with CMU was completed in March 2019. We completed our annual DNR Collectors Permit reports for fish sampling (for the 2018 field season), and Dr. Ruetz applied for a scientific collector's permit to sample fish for the 2019 field season. Dr. Ruetz is in the process of renewing our sampling protocol with IACUC for the upcoming field season.

Travis Ellens will serve as the field crew lead again for the GVSU crew in 2019. Two undergraduates have been hired as technicians to assist with sampling in the 2019 field season. Dr. Carl Ruetz and Travis Ellens attended the March 1 planning meeting for the grant in Midland, Michigan.

The GVSU crew plans to visit the eight sites they were assigned for the 2019 field season. Sampling is planned for the weeks of June 24-28, July 8-12, July 22-26 and July 29-August 2.

GVSU will continue to coordinate with the CMU, LSSU, and UND crews for a potential training day in the field prior to the start of our 2019 fieldwork.

University of Notre Dame:
Field-collected data (fish, habitat, water quality, etc.) and laboratory parameters (water chemistry, chlorophyll-a, etc.) have been entered and 100% QC'd. A total of 100% of 2018 macroinvertebrate samples have been identified, entered, and QC'd. Macroinvertebrate sample exchange with UWindsor took place in March 2019 at the CWMP meeting in Midland, MI. UND did not receive samples in return because of personnel turnover requiring retraining in invertebrate identification over the course of 2019. Reciprocal sample exchange will be reinitiated in 2020.

Analysis of 158 chlorophyll-a filter samples from Central Basin partners [CMU, GVSU, LSSU, UWN, CWS-ON (Environment Canada)] has been completed. Results have been dispersed to all partners for data entry. We followed the standard 90% buffered acetone extraction protocol with acidification and then analyzed samples in the dark using a spectrophotometer

For the 2019 field season Notre Dame has been assigned 8 sites to sample during the 2019 field season. These sites fall within the Lake Michigan, Lake St. Clair, and Lake Huron basins. We anticipate sampling all sites between June and August 2019. Scientific collectors' permits are in the process of being obtained from the states that in which these sites reside, and our IACUC is currently being renewed.

All UND core team members (PI-Gary Lamberti, Sarah Klepinger, Katherine O'Reilly, Whitney Conard) attended the February 2019 annual planning meeting. Katherine O'Reilly and Whitney Conard are returning crew leaders and Sarah Klepinger will be training to be an eventual crew leader. For the 2019 field season, we will hire one full-time seasonal field technician, and also employ hourly crew members from our lab as needed. To train new crew members and crew leaders, we will attend a June training session with other Central Basin crews, likely in Saginaw Bay, and also independently field-test the protocols with our full crew at a former benchmark site.

Eastern U.S. Regional Team: Douglas Wilcox and Katie Amatangelo (Vegetation), Chris Norment (Birds and Anurans), James Haynes (Fish), Courtney McDaniel (Macroinvertebrates), and Michael Chislock (Water Quality)

Sample Processing, Data Entry, and Quality Control Checks

The College at Brockport aquatic macroinvertebrate personnel, overseen by Dr. Courtney McDaniel, completed 100% of all macroinvertebrate identification from 2018 sampling. Dr. Michael Chislock and students in the limnology and water quality lab at The College at

Brockport completed 100% of laboratory water quality analysis. Graduate and undergraduate technicians, overseen by Dr. Douglas Wilcox and Gregory Lawrence, have entered and performed quality checks on all other data from the 2018 sampling season, including all bird, amphibian, fish, water quality, and vegetation data.

2018 Benchmarks and Data Sharing

The College at Brockport continued to sample many sites within the Rochester Embayment Area of Concern as benchmarks to aid in numerous restoration projects. Long Pond, Salmon Creek, and Buck Pond were sampled to collect data to monitor post-restoration conditions for a U.S. Fish and Wildlife Service (USFWS) restoration project. Further, data from Buck Pond continue to help evaluate prior Ducks Unlimited and Nature Conservancy restoration projects aimed at reducing invasive cattail cover and increasing nursery areas for northern pike (*Esox lucius*) and waterfowl habitat. Braddock Bay was sampled as a benchmark site in 2018 to provide continued post-restoration data for the U.S. Army Corps of Engineers (USACE) restoration project. This project aimed to reduce wave attack, wetland loss, and turbidity by re-creating the lost barrier beach, and will reduce cattail to provide spawning and nursery areas for northern pike and potential habitat for black terns (*Chlidonias niger*) and waterfowl. Lastly, The College at Brockport worked with various invasive species removal crews such as Finger Lakes Partnership for Regional Invasive Species Management (PRISM), by providing them with sightings and information on invasive plant and animal infestations.

Working with Partners in 2018

The College at Brockport worked with a handful of partners during 2018 on using the Great Lakes Coastal Wetlands Monitoring Program's (GLCWMP) sampling to assist local restoration projects. Data from fish sampling and bird and amphibian sampling at Braddock Bay were summarized and included in The College at Brockport's report to the New York State Department of Environmental Conservation (NYSDEC) and USACE to help monitor post-restoration conditions at Braddock Bay and help guide adaptive management. Further, fish, macroinvertebrate, water quality, and bird and amphibian sampling at Long Pond, Salmon Creek, and Buck Pond, provided additional post-restoration data for USFWS, that the agency can use in their evaluation of their restoration projects at those sites. GLCWMP data assisted both of these Great Lakes Restoration Initiative (GLRI)-funded projects and will help guide future restoration projects in Great Lakes coastal wetlands.

College at Brockport crews also assisted the NYSDEC and Finger Lakes PRISM by providing information on the presence and extent of invasive plant species in Great Lakes coastal wetlands. These included water chestnut (*Trapa natans*), which was found in multiple sites on the south shore of Lake Ontario. Finger Lakes PRISM, NYSDEC, and volunteer groups mobilized and removed water chestnut at many of these sites and will continue to monitor them after detections by College at Brockport crews. Further, crews detected and reported other aquatic invasive plants of interest, such as starry stonewort (*Nitellopsis obtusa*). Crews also reported sightings of an emerging invasive fish, tubenose goby (*Proterorhinus semilunaris*), to agencies in Canada, where crews found a few individuals this year.

2019 Site List and Crew Assignments

The College at Brockport has finalized its 2019 site list and is beginning preparations to have the bird and amphibian survey crews ready to sample within the next few weeks. Braddock Bay (7052), Buttonwood Creek (7026), and Cranberry Pond (50) have received benchmark designations. Sampling at Braddock Bay will assist in post-restoration data collection for the GLRI-funded restoration project conducted by USACE. Sampling at Cranberry Pond will provide pre-restoration data for a Sustain Our Great Lakes (SOGL)-funded restoration project carried out by National Audubon Society and Ducks Unlimited. Further sampling at Buttonwood Creek (7026) will help provide continued monitoring data to help guide potential restoration work supplementing previous GLRI-funded work done by Ducks Unlimited and The College at Brockport.

The College at Brockport has worked with neighboring crews to swap sites and ensure as many sites are sampled across the basin as possible. The College at Brockport received nine sites from Environment Canada between Kingston and Belleville, Ontario that will be sampled by fish, aquatic macroinvertebrate, water quality, and vegetation crews. No additional sites were picked up for the bird and amphibian crews.

The College at Brockport personnel have applied for and are awaiting access permits for sites from the NYSDEC, Pennsylvania Department of Conservation and Natural Resources, and New York State Office of Parks, Recreation, and Historic Preservation. Bird and amphibian training is underway and both crew members passed the amphibian certification exam. The crew lead has passed the bird identification certification exam as well. College at Brockport personnel have completed equipment and inventory checks to prepare for the summer fish, aquatic macroinvertebrate, water quality, and vegetation sampling. Training for these crews will begin in late May and early June prior the main sampling season.

Canadian and US Western Lake Erie Regional Team: Jan Ciborowski, Joseph Gathman (Water Quality, Fish and Macroinvertebrates), Carla Huebert (Vegetation), Doug Tozer (Birds and Anurans), and Greg Grabas and Jennifer Jung (north shore of Lake Ontario – Water Quality, Fish, Macroinvertebrates, Vegetation)

Sample Processing and Data Entry (2018)

All field data collected during the 2018 field season have been uploaded and QA'd. All fish, macroinvertebrate, macrophyte and water quality data collected in 2018 were compiled and entered into the database and quality assured over the winter. Specimens have been exchanged with companion labs (part of the reciprocal exchange of macroinvertebrate specimens to ensure consistency of identification). They will be identified in April and May 2019 and returned to the sample owners.

Field Training

Many of the individuals who will participate in fieldwork in 2019 were involved in sampling during the 2018 and earlier field seasons. Consequently, only refresher training will be undertaken for them. No new recruits are anticipated for the Tozer anuran-and-bird team. Anuran and bird surveys will occur at 55 sites and will begin shortly, as soon as overnight temperatures are above 5°C. A cold, extended winter has delayed the onset of anuran calling and mating this year.

Field crew members working with fishes, macroinvertebrates, and water quality sampling will receive orientation during the first week of May 2019 and will conduct pilot sampling at local sites on Lake Erie during late May and early June. Four members of the 6-person Windsor field crew from 2018 will be involved to some extent in training and/or field work in 2019. They will train 2-4 new senior undergraduate students who will assist during selected field trips. The Canadian Wildlife Service will have 6 personnel to conduct work on Lake Ontario in 2019, one of whom will be a new recruit (receiving training in April). Training review will include GPS use, determination of whether sites meet project criteria (open water connection to lake, presence of a wetland, safe access for crew), identification of vegetation zones to be sampled, collection of water quality samples (including preprocessing for shipment to water quality labs) and calibrating and reading field instruments and meters. Other review will include refresher instructions in setting, removing, cleaning and transporting fyke nets, and special emphasis on collection of voucher information (proper photographic procedures, collection of fin clips for DNA analysis, or retention of specimens for lab verification of identity), protocols for collecting and preserving macroinvertebrates using D-frame dip nets and field-picking. All crew members will review field data sheet entry procedures, including changes to the data sheets implemented since last field season and first-hand data-entry responsibilities after field trips. All field personnel will be given refreshers in basic fish identification training.

Several returning team members will have taken the Royal Ontario Museum course in fish identification, which is required of at least one team member in possession of an Ontario Scientific license to collect fishes. All field team members will receive field and lab safety training. Vegetation survey training will be led in early June by team leader Carla Huebert near Windsor, ON. Vegetation assistants will be introduced to the specific vegetation sampling methodology and data recording methods outlined in the QAPP.

Plans have been made for Joseph Gathman to join Valerie Brady in conducting a joint training session in Brockport, NY, in June, in order to ensure that eastern fish/invertebrate research crews are using the same field protocols.

2019 Sites and Field Preparation

New sites for 2019 have been assessed by remote examination. Preliminary assessments of site accessibility and suitability for sampling by the other teams is also complete. Correspondence is underway with landowners and First Nations to facilitate access to sites on their properties designated for surveys in 2019.

Sampling for fishes in Canada requires approval by the University of Windsor's Animal Use Care Committee as well as permits for Scientific Collection of Aquatic Species (Ontario Ministry of Natural Resources), compliance with the Province of Ontario's Environmental Protection Act (Ontario Ministry of Natural Resources), and Species At Risk (Fisheries & Oceans Canada). Fish sampling on the Ohio shores of Lake Erie requires a Wild Animal Collection permit (Ohio Department of Natural Resources), and sampling in National Wildlife Refuges in Ohio requires permits from the US Fish and Wildlife Service. Permit renewal applications are in progress to ensure approval by the start of the sampling season. Reports to the permit granting agencies for 2018 collections were submitted and approved in late fall and early winter. Detailed records of fishes caught were sent to local conservation and refuge managerial groups in Ontario and Ohio where appropriate.

Related Research in Progress

In 2015 and 2016, fish data were analyzed by graduate student Jeffrey Buckley (M.Sc. 2015) to compare the consistency of classification of wetland condition using analytical metrics derived by several different investigators. Buckley compared the newly revised wetland IBI of Cooper *et al.* (2018) with the fish quality indices of Seilheimer *et al*., and a new multivariate index (Fish Assemblage Condition Index (FACI) based on the reference-degraded continuum approach (Bhagat *et al*. in prep.). The Cooper *et al*. and Seilheimer *et al*. and FACI indices all exhibit high degrees of sensitivity and specificity to degradation by anthropogenic stress when used to assess the sites from which data were originally gathered. The indices' ability to accurately assess the condition of sites sampled over the past few years is somewhat reduced but still considered to be acceptable. This thesis will be submitted in 2019.

In summer 2017, M.Sc. student Danielle Gunsch estimated diel dissolved oxygen cycles and the associated invertebrate and fish fauna at increasing water depths within the wet meadow zone of 10 Lake Huron wetlands (5 reference wetlands and 5 draining agricultural watersheds). The duration of hypoxia (DO concentrations <4 mg/L) ranged from as much as 20 h in shallow (30-cm deep) locations to as little as 4 h in deeper water. Wetlands adjacent to agricultural lands exhibited greater daytime supersaturation than paired reference sites draining woodland.

However, seiche effects often reversed expected day/night patterns. Differences in the abundance of the most commonly encountered large invertebrates tended to be greater between regions (North Channel of Georgian Bay vs. Bruce Peninsula wetlands) than among transects arranged along a depth/dissolved oxygen gradient within each wetland. Nevertheless, significant differences in abundance of coenagrionid damselflies, *Gammarus* and *Hyalella* amphipods, and flatworms were observed among transects, particularly in North Channel wetlands.

Complementary work by Christopher Payne (Hon B.Sc. 2018) compared the community composition of invertebrate samples collected at DO logging stations by field picking using standard CWM macroinvertebrate protocols with field-preserved samples that are processed in the laboratory. As hypothesized, samples acquired by field-picking had a slightly larger size-frequency distribution and slightly lower (5%) tax richness than complementary laboratory-sorted samples. Hilsenhoff tolerance scores calculated for both types of sampling were slightly lower (i.e. taxa were more intolerant) when calculated from field-picked than from laboratory-sorted samples for 3 of 5 wetlands assessed.

Ultimately, these projects are expected to provide new fish and benthic invertebrate measures sensitive to the effects of agricultural activity in wet meadow regions of wetlands.

Zoobenthic data collected by sweep net sampling at 15 Lake Huron wetlands in 2015 by Jasmine St. Pierre (M.Sc. 2016) were sorted, identified and analyzed by Noelle Meunier (Hon. B.Sc. 2019) to test and validate St. Pierre's newly derived Zoobenthic Assemblage Condition Indices of the effects of watershed-based stresses on community composition.

During the summer of 2018, Stephanie Johnson and Joseph Gathman continued a project to survey zooplankton (Cladocera, Copepoda, Rotifera) communities of selected coastal wetlands. Sample processing is continuing, resulting in species lists occurring in selected microhabitats. This work is important because very little work has been published on the microcrustacean/ meiofauna communities of coastal wetlands.

In 2018, we began a pilot study 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 an Onset Hobo water level logger within each of 20 wetlands during the time that fyke nets were in place. Colleagues from other CWM teams have also been contributing data from late season sampling efforts. We also installed one or more Onset Hobo dissolved oxygen (DO) loggers and light temperature recorders at the location of each fyke net in each wetland for the 18-24 h corresponding to the duration of fyke net sets. Preliminary data indicate that wind action can dramatically influence water quality parameters (particularly temperature and dissolved oxygen concentrations). Even in the absence of significant seiches, daytime winds bring cool, normoxic water into wet meadow areas whereas night-time calm periods can result in rapid anoxia as water flows from shallow meadow areas into emergent and submergent areas. We hypothesize that these patterns can influence the numbers and species of fishes caught during a fyke net set.

We anticipate that all CWM teams will deploy water level loggers during their fish sampling periods in 2019. Those records are expected to yield improved understanding of the factors contributing to variability in fish catches, and that they will help define the environmental suitability of areas for mobile fishes and the likelihood of capturing them.

In supplemental work, Nathan Tuck and assistants will deploy water level and dissolved oxygen loggers for the entire sampling season in 3 Lake Erie wetlands. Nathan will set fyke nets repeatedly over the summer during paired seiche/calm weather periods in each wetland to determine how water level and dissolved oxygen conditions influence synoptic estimates of fish community composition.

Building Interactions with Stakeholders and Collaborators

The University of Windsor crew have been coordinating with appropriate personnel to plan upcoming visits to several sites of conservation and/or restoration importance in Ohio. In 2019, fish/Invertebrate/plant crew members will return to sample Mentor Marsh, where restoration efforts have been underway for several years to control *Phragmites* and encourage the restoration of native-plant communities. Previous visits in 2012, 2015 and 2018 have provided prior data against which the new, post-restoration data can be compared.

Sturgeon Creek Restoration Project (Essex County, Ontario) was newly created in 2018 from a former marina by a partnership between Caldwell First Nation and the Essex Region Conservation Authority. This wetland was designated as a benchmark site but we were unable to sample due to access problems. We will sample it in 2019.

Also in 2019 we will sample Lake Pond on Point Pelee and part of Point Pelee National Park. Storm surges in late summer 2018 created a breach along the east shore, permitting water exchange with Lake Erie. Park personnel have invited us to sample this and other wetlands in the Park as part of their centennial Bioblitz program and in anticipation of a new restoration program to control *Phragmites* and *Typha* encroachment into open water parts of their marshes.

Coastal wetland information is being shared with two Canadian consortia to further responsibilities under the Great Lakes Water Quality Agreement.

Firstly, in 2018 benthic invertebrate data from Lake Erie basin wetlands were used by the Nearshore Framework subcommittee of Annex 2 as part of an overall assessment of the environmental condition of the Canadian coastal margin of Lake Erie and the St. Clair-Detroit River System.

Additionally, the Detroit River Canadian Cleanup group (responsible for Canadian waters of the Detroit River Area of Concern) is comparing fish, aquatic invertebrate, vegetation and water quality data collected by various consortia to determine criteria by which to delist several Beneficial Use Impairments. We compiled CWM information from all available sites on Lake Erie and in the St. Clair-Detroit River system to determine if thresholds in biological condition could be detected that could contribute to assessment of Impaired Uses #2 (Macroinvertebrates), #3 (fishes) and #11 (Aquatic Habitat). Preliminary analysis suggests that bird IEC scores are informative in assessing thresholds in the amount of agricultural vs. developed land in watersheds and that fish and invertebrate indices reflect local water quality independently of habitat condition *per se* (Ciborowski *et al*. 2019).

Wikwemikong First Nations, Manitoulin Island, ON, (Liaison - John Manitowabi). In 2018, we were able to arrange joint sampling, and discussed collaboration to better assess wetland condition in First Nation areas of Manitoulin Island. We anticipate continued collaboration in 2019.

Assessing and Enhancing the Resilience of Great Lakes Coastal Wetlands. In December 2017, Environment and Climate Change Canada (ECCC) began the *Great Lakes Protection Initiative* (GLPI) to address the most pressing challenges affecting Great Lakes water quality and aquatic ecosystem health. CWM coPIs have been asked to contribute their expertise in contributing to a new 5-year study entitled “Assessing and Enhancing the Resilience of Great Lakes Coastal Wetlands”. Its goals include assessing the vulnerability of coastal wetlands to climate change impacts and other stressors, and identifying adaptive measures to increase the resilience of coastal wetlands. The group will be conducting field surveys and spatial analysis to develop models of response to climate change at 25 Canadian wetlands, most of which are part of the CWM sampling program. We anticipate that there will be significant value added through continued cooperation on this important initiative.

ASSESSMENT AND OVERSIGHT

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

For the second 5-year sampling rotation, no substantial methodological or quality assurance/quality control changes were necessary. The QAPP_r5 document was reviewed by project PIs prior to our February 19, 2016 project meeting. The only changes that were required to QAPP_r5 related to the data management system. Specifically, an update was added noting how the data management system developed by LimnoTech and housed at Central Michigan University will be backed up. Project PIs signed the updated QAPP (QAPP_CWMII_v1) at the February 19, 2016 meeting. 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 were made. PIs signed off on these changes at the 2018 PI meeting in Michigan in February.

In 2018 the bird sampling protocol was changed from a 15 minute listening period to a 10 minute listening period to match sampling protocol changes made by the Marsh Monitoring Program. The avian ecologist PIs have made the decision that it is best to keep CWMP protocols matching Marsh Monitoring Program protocols to ensure that data can be shared between these two programs. Preliminary data analyses indicate that there is likely to be little effect on the birds detected under this new protocol and, thus, the data collected going forward should still be quite comparable to the previously collected data.

In early 2019 the water quality portion of the QAPP and the water quality SOP underwent an extensive review by several PIs who oversee water quality sampling. A number of updates and clarifications were made to the SOP. Nearly all of these updates were to increase clarity of the methods and to increase consistency between the 2 documents. The water quality SOP was also re-formatted to match the formatting of other program SOPs. While these updates will not change methodology in the field or lab, they will improve clarity and consistency between the QAPP and SOP. One additional change that was made to the QAPP as well as fish and macroinvertebrate SOPs involves methods for estimating vegetation and substrate coverage as a co-variate when sampling fish and inverts. We've separated benthic vegetation coverage from water surface coverage to make these estimates more straightforward for field crews.

Major QA/QC elements that were carried out over the previous 12 months include:

- Training of all new laboratory staff responsible for macroinvertebrate sample processing: This training was conducted by experienced technicians at each regional lab and was overseen by the respective co-PI or resident macroinvertebrate expert. Those labs without such an expert sent their new staff to the closest collaborating lab for training. 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, amphibian, and water quality field crew members following the QAPP and SOPs. This included passing tests for procedural competence, as well as identification tests for fish, vegetation, birds, and amphibians. Training certification documents were archived with the lead PI and QA managers.

- GPS testing: Every GPS unit used during the 2018 field season was tested for accuracy and its ability to upload data. Field staff collected a series of points at locations that could be recognized on a Google Earth image (e.g., sidewalk intersections) then uploaded the points to Google Earth and viewed the points for accuracy. Precision was calculated by using the measurement tool in Google Earth. Results of these tests have been archived and referenced to each GPS receiver by serial number.

- Review of sites rejected after initial site visits: In cases where a site was rejected during a site visit, the reason for rejection was documented by the field crew in the site selection database. The project QA officers (Brady and Cooper) then reviewed these records to ensure consistency among crews. Occasionally, field crew leaders contacted Uzarski, Brady, or Cooper by cell phone, text, or e-mail when deciding whether to reject a site. However, given that most crew leaders have been with the project for over 5 years, they are able to make these decisions independently in many cases. Also, most sites currently being visited were sites sampled in the first round (2011-2015) so crew leaders are familiar with most wetlands.

- Collection and archiving of all training/certification documents and mid-season QA/QC forms from regional labs: These documents are converted PDF 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 are being evaluated using duplicate samples. Duplicate water quality samples were collected at approximately every three sites sampled. A summary of these results is included below.

- QC checks for all data entered into the data management system (DMS): Every data point that is entered into the DMS is being checked to verify consistency between the primary record (e.g., field data sheet) and the database. This has been completed for 2011-2018 data.

- Linking of GPS points with field database: Inevitably, 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. Database managers have been working diligently to increase the matching between uploaded GPS points and the field database and the vast majority of the GPS points have now been matched with their point-level data.

- 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 (see example report below).

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 from 2018 have passed the criteria shown below (Table 17).

Table 17. 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 each year of the program is shown in Table 18. 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 or personnel at the respective analytical lab 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 18 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 18. 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 enters its ninth year (fourth field season of round 2). 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 many conference calls and e-mail discussions regarding field work, taxonomic changes, data analysis, indicator refinement, and publications throughout the duration of the project. Most PIs will spend the first week of field season in the field with their crews to ensure that all protocols are being followed according to the standards set forth in the QAPP and SOPs and to certify or re-certify crew members. Most crews have returning and experienced personal. 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 crew questions.

Overall

The quality management system developed for this program 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 very successful and we expect the 2019 field season to be the same.

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. This will allow us to use these data to test the usefulness of metabarcoding for Great Lakes surveillance to provide groups 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 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 were 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, has developed a DSS for wetlands from Saginaw Bay to Western Lake Erie and is now expanding into other areas of the Great Lakes.

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

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

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

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

Buck Pond West and Buttonwood Creek, Lake Ontario, Sedge Meadow Restoration: These two wetlands in the Rochester Embayment AOC are actively being restored by a consortium involving Ducks Unlimited, The College at Brockport, NYS Department of Environmental Conservation, and the Town of Greece. CWM crews collected pre-restoration data as a benchmark site to help plan and implement restoration activities. Post-restoration data collection is underway under CWM to help assess results and help build a model for future sedge meadow restoration in Lake Ontario to mitigate the harmful impacts of invasive cattails and provide habitat for fish and wildlife species.

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

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

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

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

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

Green Bay Area Wetlands: Data from the benchmark site Suamico River Area Wetland was requested by and shared with personnel from the Wisconsin Department of Natural Resources and The Nature Conservancy, who are involved in the restoration activities to re-connect a diked area with Green Bay. In 2011 NRRI sampled outside the diked area following CWM methods, and in 2013 we sampled within the diked area as a special request. The data were summarized for fish, invertebrates, water quality, birds, and vegetation and shared with David Halfmann (WDNR) and Nicole Van Helden (TNC). We have ongoing communication with TNC members and plan to re-sample of this site in 2015.

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

Support for Un-affiliated Projects

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

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

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" (SOGL) funding and other programs. SOGL 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 amphibian communities in Lake Ontario coastal wetlands (The College at Brockport)
- A fish-based index of biotic integrity for Lake Ontario coastal wetlands (The College at Brockport)
- Modeling potential nutria habitat in Great Lakes coastal wetlands (Central Michigan University)
- Modeling of Eurasian ruffe (*Gymnocephalus cernua*) habitat preferences to predict future invasions (University of Minnesota Duluth in collaboration with USEPA MED)
- Modeling species-specific habitat associations of Great Lakes coastal wetland birds (University of Minnesota)
- The effect of urbanization on the stopover ecology of Neotropical migrant songbirds on the western shore of Lake Michigan (University of Minnesota Duluth).
- Nutrient limitation in Great Lakes coastal wetlands: gradients and their influence (Central Michigan University; with additional funding from the CMU College of Science and Engineering)
- Invasive *Phragmites australis* management (Central Michigan University; with additional funding from the CMU College of Science and Technology)
- The relationship between vegetation and ice formation in Great Lakes coastal wetlands (Central Michigan University; with additional funding from CMU College of Science and Engineering)
- 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.

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

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.

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.

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.