Implementing the Great Lakes Coastal Wetland Monitoring Program

Semiannual Progress Report

October 1, 2019 – March 31, 2020

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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 are now completing the second phase of this work. The status of the work has been changed from a project to a sampling program, and we will soon finish sampling all the wetlands again for the second time. During this second round (2016-2020), we are investigating adjustments to our indicators to ensure that water level fluctuations are taken into account. We also continue to support on-the-ground restoration projects by providing data and the interpretation of those data.

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 method 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.

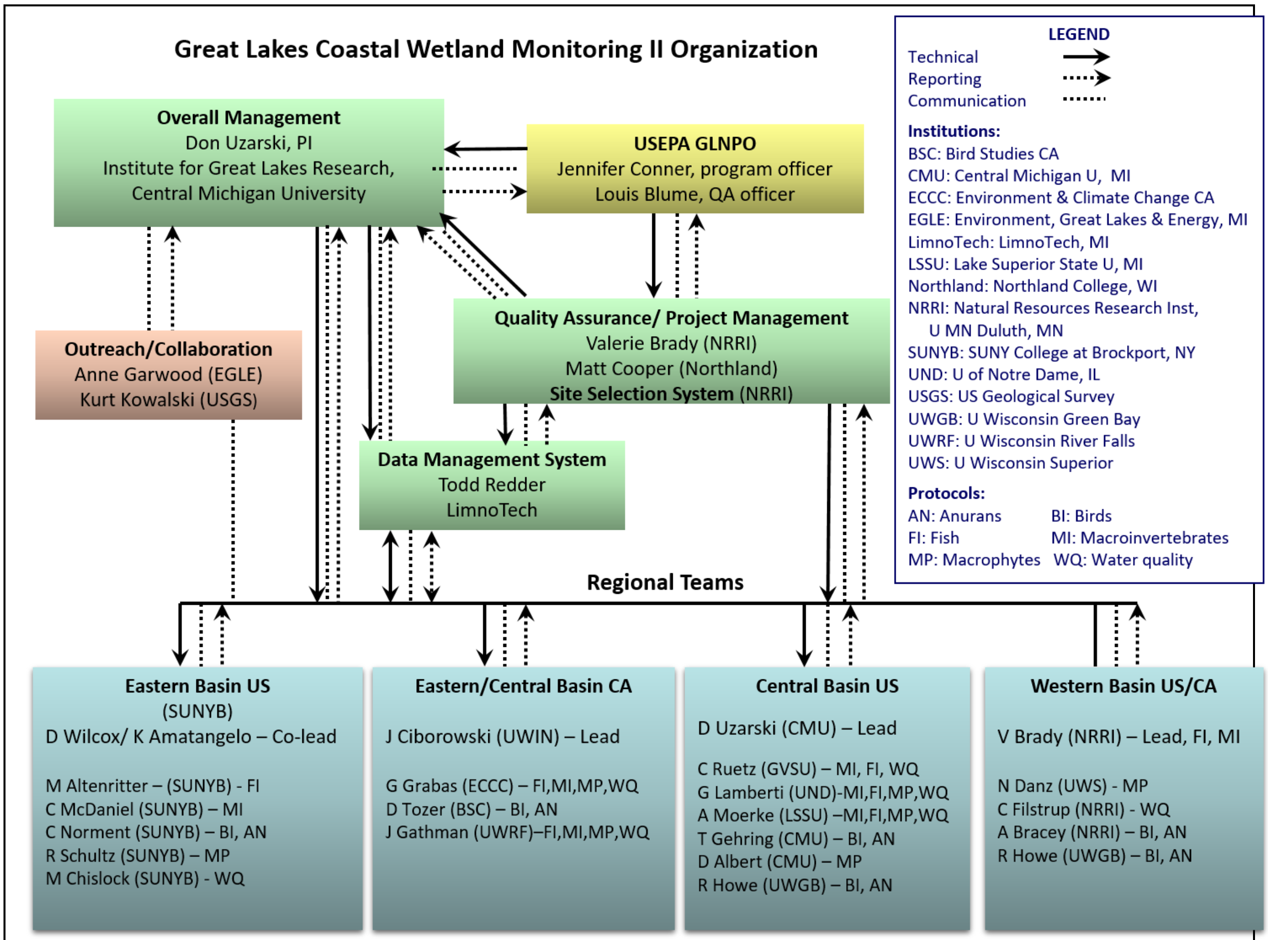

Figure 1. Organizational chart for the program showing lines of technical direction, reporting, and communication separately.

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, 2019 – Mar. 31, 2020)**	**Project Status** (Not Started; Started; Paused; 25% Completed; 50% Completed; 75% Completed; 95% Completed; and 100% Completed)
4.1.3	Number of Great Lakes coastal wetlands assessed for biotic condition	212*	75% completed

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

SITE SELECTION

Year ten site selection was completed in February 2020. 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 2015. 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 2015 and 2020.

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, 2016, and 2020

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).

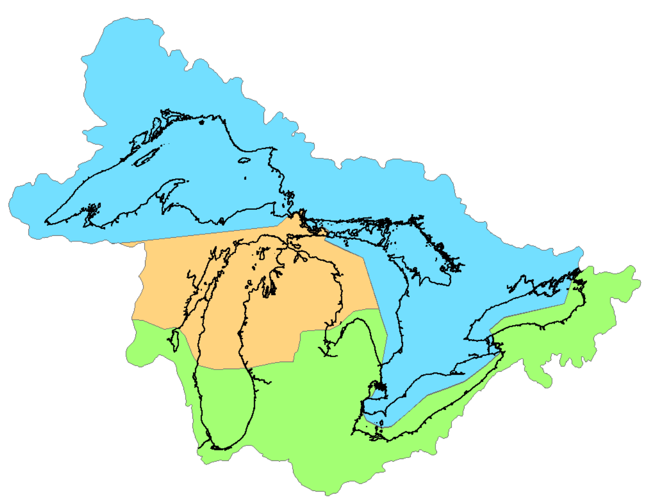

Figure 2. Divisions of lakes into regions. Note that stratification is by region *and* lake, so northern Lake Erie is not in the same region as Lake Superior, etc.

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 2020, when panel *E* is being sampled for the second time, the 20 sites in sub-panel *b* of panel *D* will be re-sampled. 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 access	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 selected, 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.

2020 Site Selection

For 2020, 214 sites have been selected for sampling (Figure 3). Of these, 17 are benchmark sites. Another 19 sites are resample sites and 19 are pre-sample sites, which will be resample sites next year (2021). 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 2020 sites were sampled in 2015, 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 2020 as has occurred since 2016.

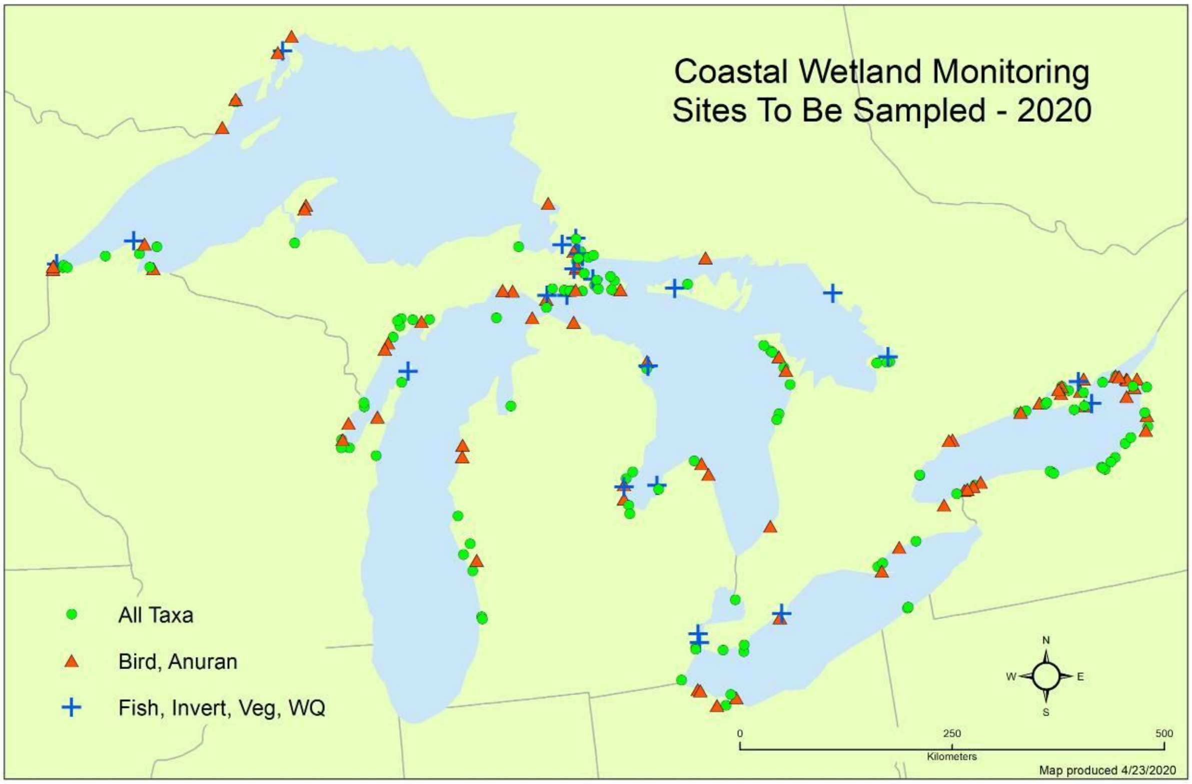

Figure 3. Locations of the 214 Great Lakes coastal wetlands to be sampled in 2020, color-coded by taxonomic groups. Sites assigned only to bird and anuran crews (due to their greater sampling capacity) are shown with a red triangle sign.

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.

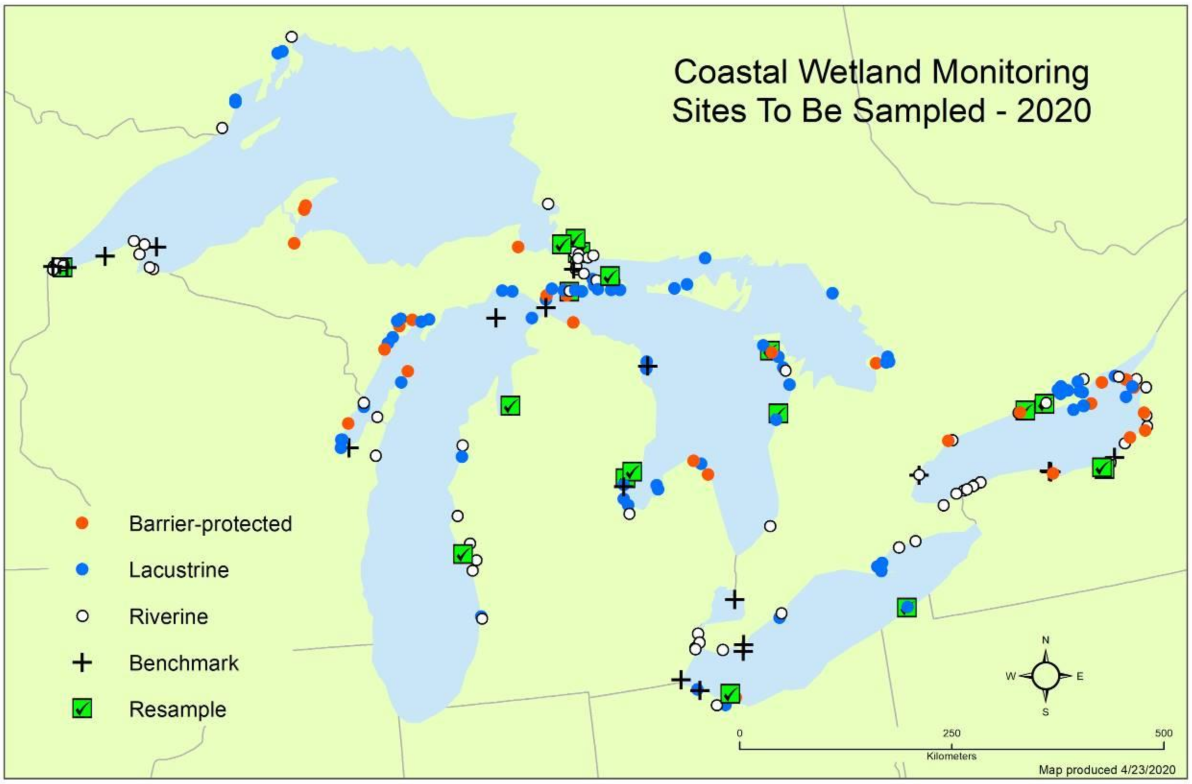

Figure 4. Locations of the 214 Great Lakes coastal wetlands to be sampled in 2020, color-coded by site type. See text for description of site types.

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.

Training for fish and invertebrate crews will now include specific instructions for sampling in deep water. These techniques were trialed in 2019 and found to work to allow sampling in at least somewhat deeper water than we have been sampling. Specifically, to sample invertebrates in depths greater than 1 m, D-frame dip net handles were extended and sampling was done from the boat by moving around the boat and by allowing the boat to swing around one of its anchors. To set fyke nets in deeper water, the boat can be used to set the cod end of the net and the frame can be set underwater, using rock bag anchors to weight the cod end.

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 anuran calls). Passing a given exam certifies the individual to perform the respective sampling protocol(s). Since not every individual is responsible for conducting every sampling protocol, crew members 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, 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 macrophytic vegetation, fish, macroinvertebrates, anurans and birds. Separate data entry/editing forms are created for data entry based on database table schema information that is stored in a separate PostgreSQL schema. 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 2019 field season.

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'd 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. Nightly database backups are automatically uploaded to a dedicated folder on LimnoTech's Sharefile system where they are maintained on a 30-day rolling basis. In the event of significant database corruption or other failure, a backup version can be restored within an hour with minimal data loss. The server that houses the DMS has also been configured to use CMU's Veeam Backup Solution. This backup solution provides end-to-end encryption including data at rest. Incremental backups are performed nightly and stored at secure locations (on premise and offsite). Nightly backup email reports are generated and sent to appropriate CMU IT staff for monitoring purposes. Incremental backups are kept indefinitely and restores can be performed for whole systems, volumes, folders and individual files upon request.

RESULTS-TO-DATE (2011-2019, with exceptions noted)

A total of 176 wetlands were sampled in 2011, with 206 sampled in 2012, 201 in 2013, 216 in 2014, and 211 in 2015 our 5th and final summer of sampling for the first project round. Overall, 1010 Great Lakes coastal wetland sampling events were conducted in the first round of sampling (2011-2015; Table 5), and we have now nearly completed sampling these wetlands a second time for the second complete round of coastal wetland assessment, 2016-2020. Note that this total number is not the same as the number of unique wetlands sampled because of temporal re-sampling events and benchmark sites that are sampled in more than one year. For the second round of sampling, we sampled 192 wetlands in 2016, 209 wetlands in 2017, 192 wetlands in 2018, and 211 wetlands in 2019.

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, we have sampled most 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 2019, 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%
2019	76	36%	7,746	20%
CA total Round 2	**276**	**34%**	**23,444**	**18%**
United States				
Round 1 (2011 – 2015)				
2011	126	72%	22,008	87%
2012	124	60%	21,845	73%
2013	130	65%	18,939	73%
2014	144	67%	26,836	80%
2015	134	64%	26,681	73%
US total Round 1	**658**	**65%**	**116,309**	**77%**
Round 2: 2016 – 2020				
2016	129	67%	24,446	85%
2017	139	67%	30,703	80%
2018	125	65%	17,715	82%
2019	135	64%	30,281	80%
US total Round 2	**528**	**66%**	**103,538**	**82%**
Overall Totals Round 1	**1010**		**151,446**	
Overall Totals Round 2	**804**		**126,982**	

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.

Wetlands contained 24 to 29 bird species on average; some sampled benchmark sites had only a couple of bird species, but richness at high quality sites was as great as 64 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 2019.

Country	**Site count**	**Mean**	**Max**	**Min**	**St. Dev.**
Birds					
Can.	535	28.7	64	8	10.2
U.S.	995	23.6	60	2	10.6
Amphibians					
Can.	488	4.6	8	0	1.7
U.S.	898	4.1	8	0	1.4

Bird and anuran data in Great Lakes coastal wetlands by lake (Table 8) shows that wetlands on most lakes averaged around 25 bird 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.

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 2019.

	Birds				Anurans			
Lake	**Sites**	**Mean**	**Max**	**Min**	**Sites**	**Mean**	**Max**	**Min**
Erie	181	28.7	54	0	191	3.7	7	0
Huron	465	25.5	64	0	397	4.4	8	0
Michigan	271	25.6	60	0	243	3.9	7	0
Ontario	402	23.4	54	0	380	4.8	8	1
Superior	211	25.9	52	0	175	3.9	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 2019.

Country	Sites	Mean	Max	Min	St. Dev.
Overall					
Can.	290	9.9	23	2	3.8
U.S.	633	12.7	28	2	5.0
Non-natives					
Can.	290	0.7	4	0	0.9
U.S.	633	0.9	6	0	1.0

From 2011 through 2019, we collected 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.

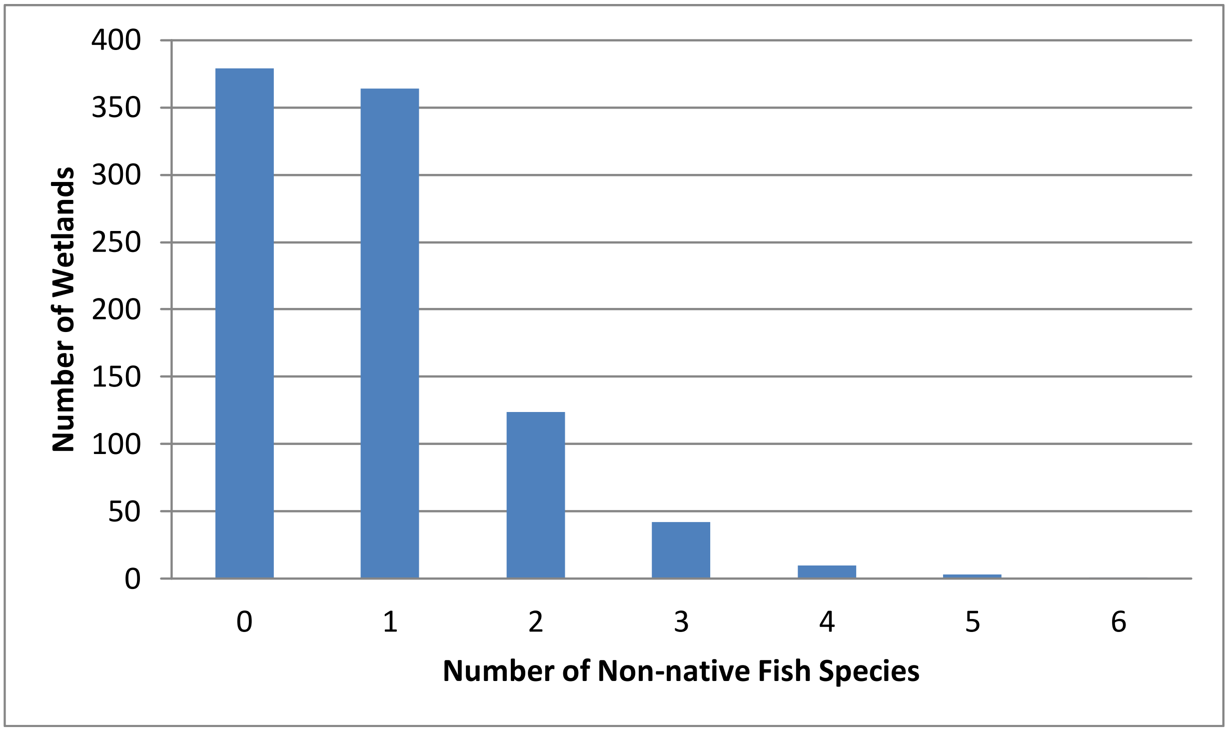

Figure 5. Number of Great Lakes coastal wetlands containing non-native fish species. Data from 2011 through 2019.

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 1.4 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 2019.

		Fish (Total)			Non-native		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	126	11.1	27	2	1.4	5	0
Huron	315	11.6	27	2	0.6	3	0
Michigan	146	12.5	28	4	1.0	5	0
Ontario	218	11.3	23	2	0.9	4	0
Superior	118	13.2	28	3	0.95	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 2019.

Country	Sites	Mean	Max	Min	St. Dev.
Overall					
Can.	355	38.2	76	13	11.3
U.S.	703	39.1	86	12	12.9
Non-natives					
Can.	355	0.6	4	0	0.9
U.S.	703	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.

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 2019.

		Macroinvertebrates (Total)			**Non-native**		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	137	34.7	69	12	0.9	4	0
Huron	356	41.6	80	13	0.7	5	0
Michigan	165	40.4	86	14	0.8	3	0
Ontario	242	33.7	62	12	0.8	4	0
Superior	138	42.7	69	15	0.2	2	0

There is little variability among lakes in non-native taxa occurrence, although Erie, Huron, and Ontario had wetlands with 4-5 non-native taxa (Table 12, Figure 6). 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.

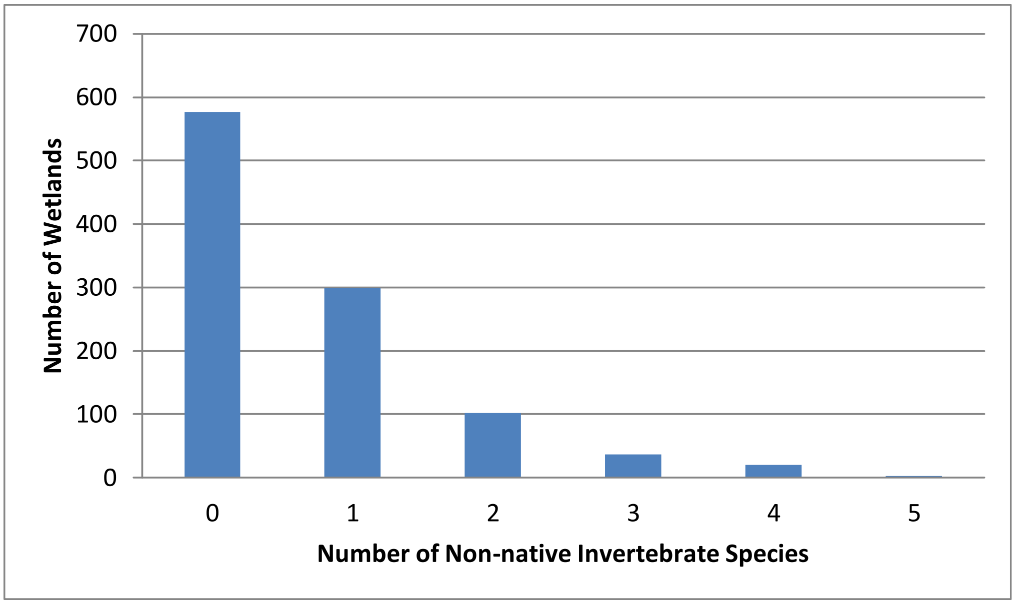

Figure 6. Number of Great Lakes coastal wetlands containing non-native invertebrate species. Data from 2011 through 2019.

In 2014, we realized that we are finding some non-native, invasive species in significantly more locations around the Great Lakes than are being reported on nonindigenous species tracking websites such as the USGS's Nonindigenous Aquatic Species (NAS) website (http://nas.er.usgs.gov/). Locations of aquatic macroinvertebrates are particularly under-reported. The best example of the difference is shown in Figures 7 and 8 for the faucet snail, *Bithynia tentaculata*. Figure 7 shows the range portrayed on the USGS website for this snail before we reported our findings. Figure 8 shows the locations where our crew found this snail. Finally, Figure 9 shows the USGS website map after it was updated with our crews' reported findings.

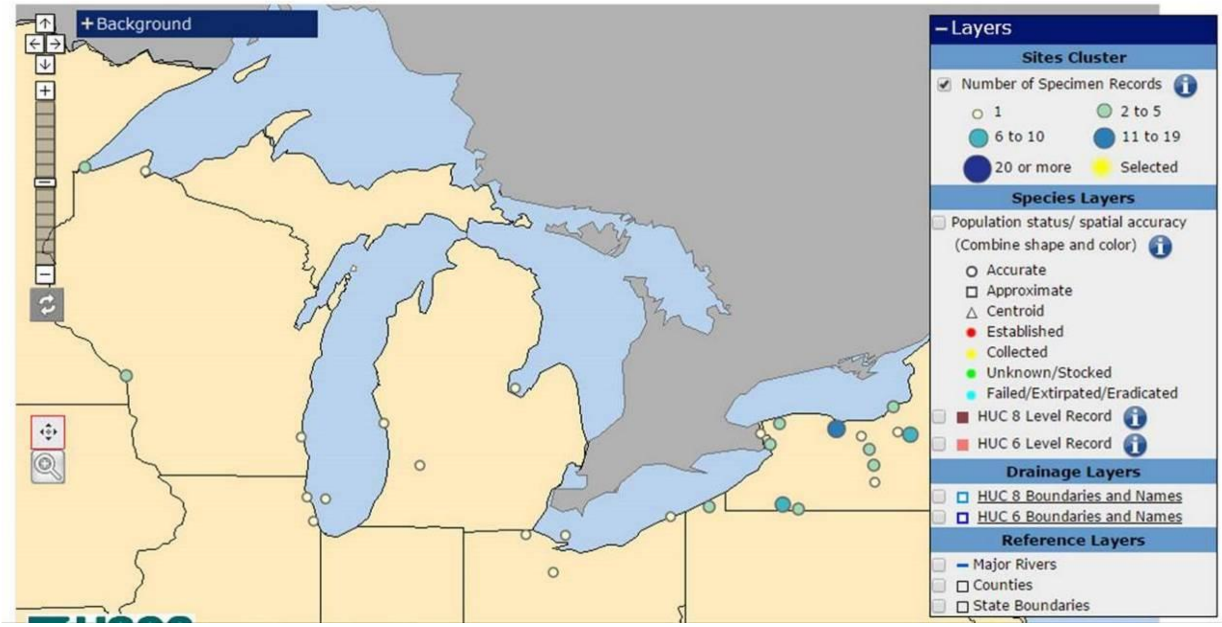

Figure 7. Locations of *Bithynia tentaculata* in USGS NAS website PRIOR to our project providing additional locations where they were collected.

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

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

In collaboration with the Great Lakes Environmental Indicators project and researchers at the USEPA Mid-Continent Ecology Division in Duluth and at the University of Wisconsin Superior, a note was published in the *Journal of Great Lakes Research* about the spread of *Bithynia* in Lake Superior (Trebitz et al. 2015). A second publication focusing on the factors that may contribute to *Bithynia* invasion, authored by CWMP scientists, was recently published in the journal, *Biological Invasions* (Schock et al. 2019).

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

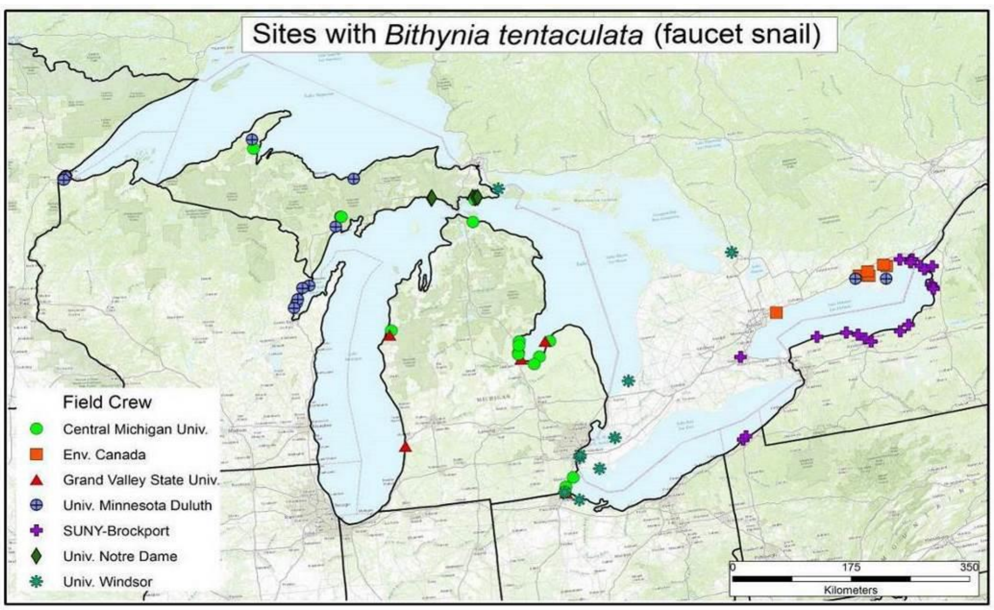

Figure 8. Locations of *Bithynia tentaculata* found by CWM crews, 2011 - 2013.

On average, there were approximately 40 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 none), particularly in highly impacted areas that were no longer wetlands but were sampled because they are designated for restoration and because of high water levels along higher energy coastlines.

Non-native vegetation is commonly found in Great Lakes coastal wetlands. We have updated our plant taxa lists to ensure that we are correctly coding all non-native macrophyte taxa, even those that are not invasive but remain well-behaved members of the wetland macrophyte community. That has changed the numbers of non-native species for many wetlands because in the past we had focused more on the non-natives that are invasive and are problematic in wetlands.

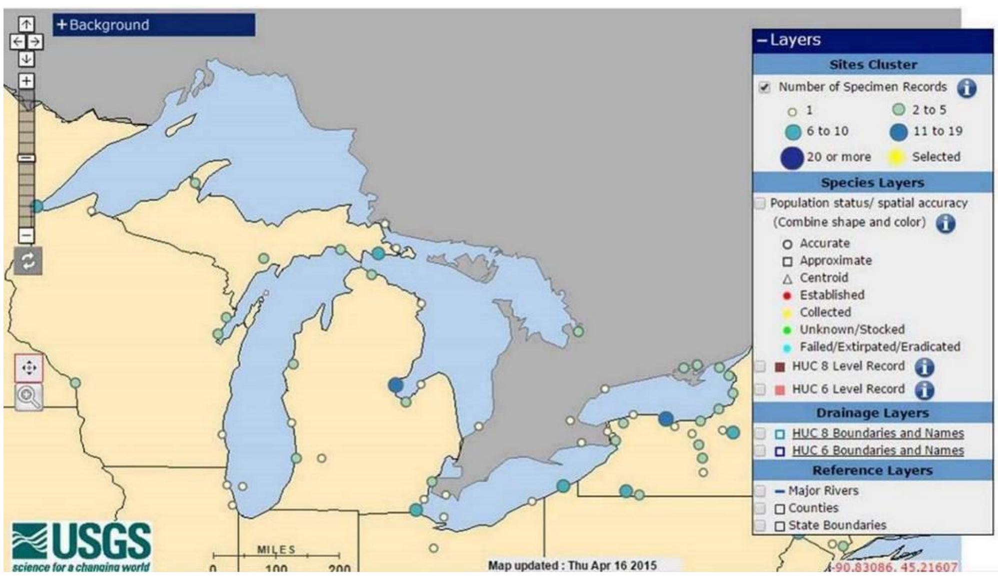

Figure 9. Locations of *Bithynia tentaculata* in USGS NAS website AFTER our project provided additional locations where they were collected; compare to Figure 6.

Coastal wetlands averaged about 5 non-native species (Table 13). Some wetlands contained as many as 21 non-native macrophyte species, but there were wetlands in which no non-native plant species were found. It is unlikely that our sampling strategy would miss significant non-native plants invading 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.

Table 13. Total macrophyte species in Great Lakes coastal wetlands, non-native species and US at-risk species; summary statistics by country. Data from 2011 through 2019 for total species and invasives; data from 2011-2015 for US at-risk species.

Country	Site count	Mean	Max	Min	St. Dev.
Overall					
Can.	355	40.0	87	6	16.6
U.S.	706	40.8	100	0	17.0
Non-native					
Can.	355	5.2	14	0	2.9
U.S.	706	4.8	21	0	3.2
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 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 non-native species were highest in Lake Ontario and lowest in Lake Superior wetlands. Lake Superior had the lowest maximum number of non-native macrophytes in a wetland and Lake Huron had the highest maximum number with 21. Most lakes had some wetlands in which no non-native plants were found.

Table 14. Macrophyte 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 2019.

		Macrophytes (Total)			Non-native		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	147	25.2	69	1	5.6	17	0
Huron	356	47.6	100	4	4.2	21	0
Michigan	158	44.1	83	4	5.2	12	0
Ontario	262	39.0	87	8	6.9	15	1
Superior	138	37.7	77	0	2.0	7	0

Our macrophyte data have reinforced our understanding of the numbers of coastal wetlands that contain non-native plant species (Figure 10). Only 6% of 1053 sampled wetlands lacked non-native species, leaving 91% with at least one. Sites were most commonly invaded by up to 7 non-native plant species and 19% of sites contained 8 or more non-native species. Detection of non-native 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 non-natives in some wetlands.

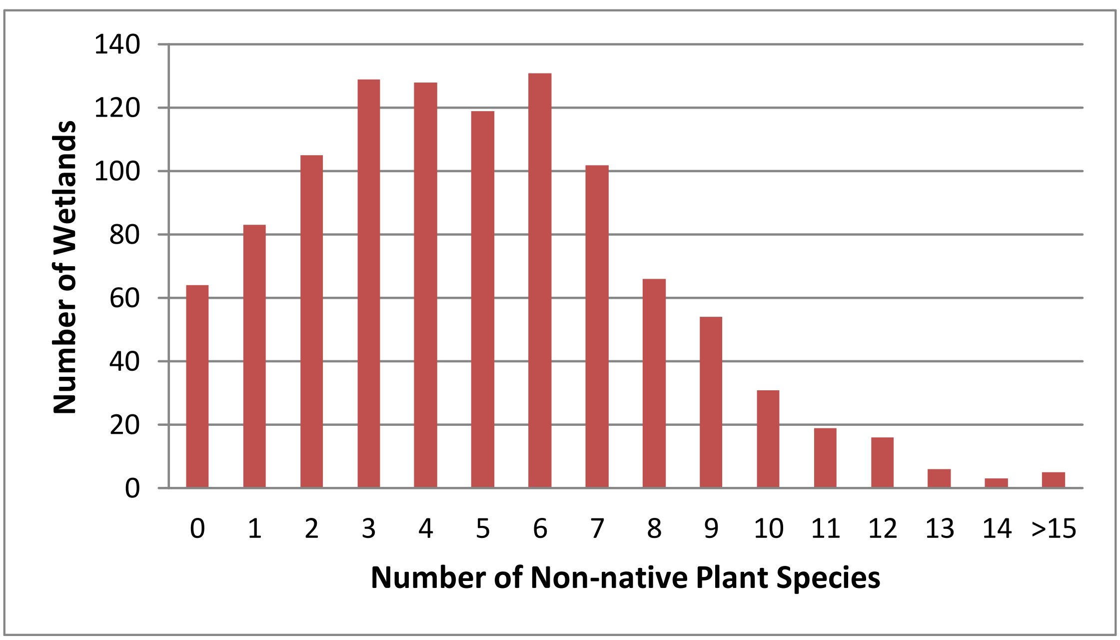

Figure 10. Number of Great Lakes coastal wetlands containing invasive plant species based on 2011 through 2019 data.

As an example for the state of Michigan, we also looked at wetlands with both invasive plants and plant species considered “at risk” (Figure 11). We found that there were a few wetlands at all levels of invasion that also had at-risk plant populations. This information will be useful to groups working to protect at-risk populations by identifying wetlands where invasive species threaten sensitive native species.

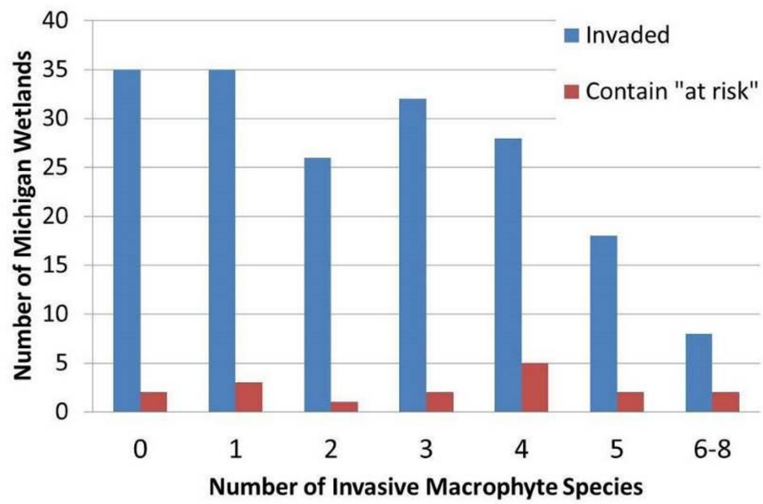

Figure 11. Number of state of Michigan Great Lakes coastal wetlands containing both invasive plant species and “at risk” plant species, based on 2011 through 2014 data.

We created a map of invasion status of Great Lakes coastal wetlands using all invasive species data we collected through 2014 for all taxonomic groups combined (Figure 12). Unfortunately, this shows that most sites have some level of invasion, even on Isle Royale. However, the more remote areas clearly have fewer invasives than the more populated areas and areas with relatively intense human use.

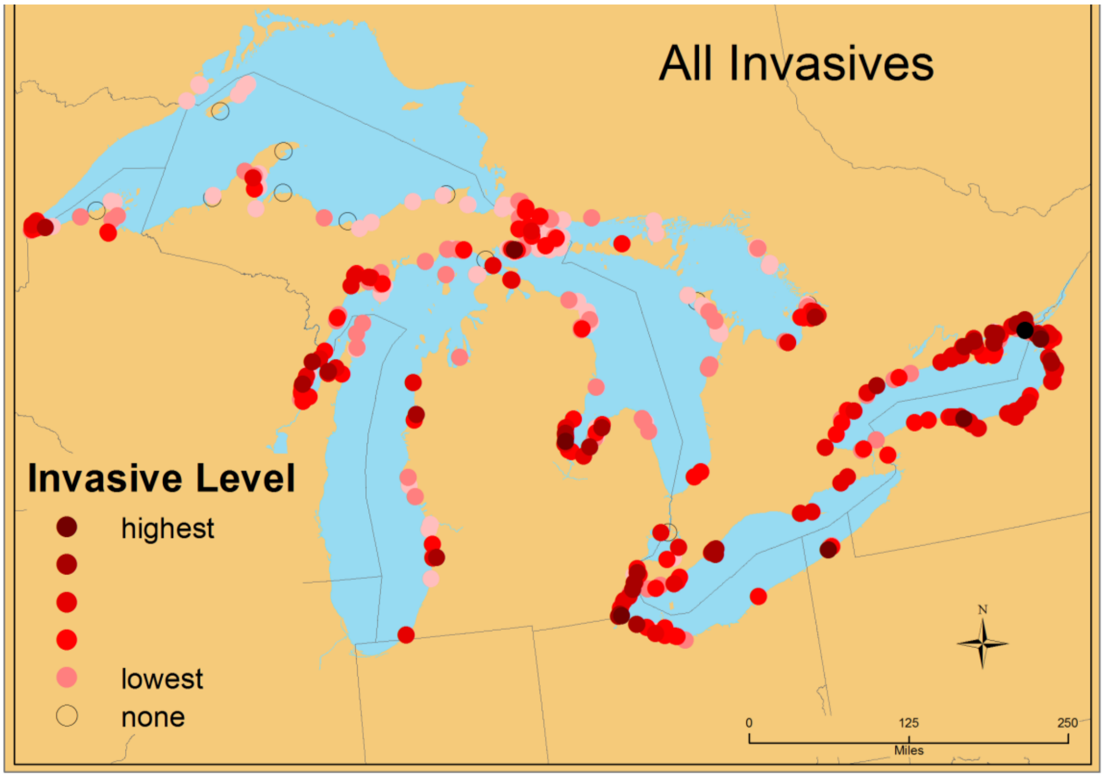

Figure 12. Level of "invadedness" of Great Lakes coastal wetlands for all non-native taxa combined across all taxonomic groups, based on data from 2011-2014.

Wetland Condition

In the fall of 2012 we began calculating metrics and IBIs for various taxa. 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 13) 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

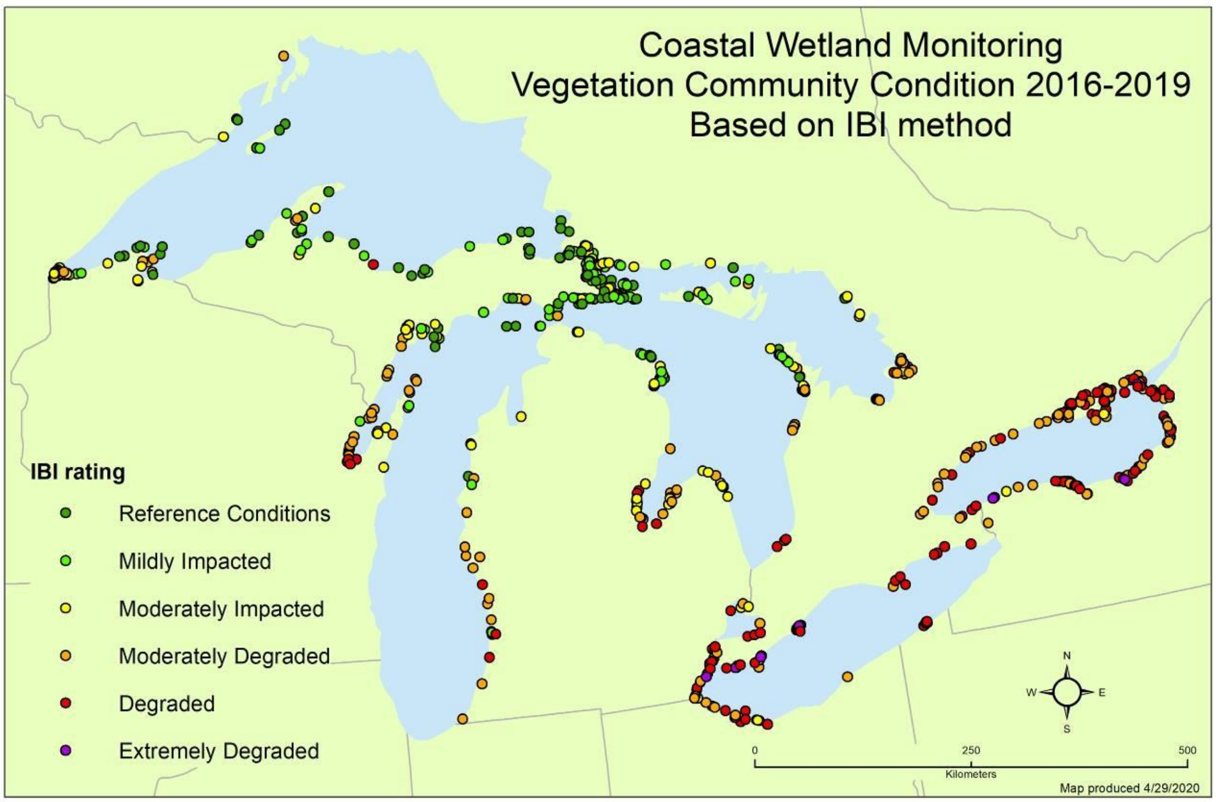

Figure 13. Condition of coastal wetland vegetation at sites across the Great Lakes. Circle color indicates vegetation community quality. The indicator is labeled "draft" while this indicator is investigated for robustness against varying water levels and latitude. Based primarily on data collected between 2016 and 2019.

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.

This IBI has been updated and adjusted multiple times since the start of the project, accounting for the shift in condition scores at some sites. The first adjustment was necessary to reflect changes in the taxonomic treatment of many marsh plants in the 2012 Michigan Flora and Flora of North America. In spring 2020, Dr. Dennis Albert, with assistance from Allison Kneisel, reviewed the data input file for the plants, looking at each individual species (taxa) on the list and observing how many records of each taxon were in the database. First, redundant entries were removed; some taxa had several synonyms in the database. The next step was to remove species that had no occurrences over 9 years of data collection; this eliminated 2082 species or 49.6% of the original species from the data input file.

A final step was to review the database for upland species or species that were outside of their accepted range. Some of these were clearly errors that resulted from the dropdown menu. For example, *Carex oligosperma*, a common northern wetland sedge, was recorded along several transects over several years in a Lake Superior wetland, but then *Carex oligocarpa*, an upland sedge immediately next to *C. oligosperma* on the dropdown list, was recorded at several points along a single transect. This was clearly a data recording error. Similar errors were identified for a handful of species. Another type of error that was identified and corrected in the database occurred when a species was noted that had a range north or south of the Great Lakes but appears very similar to a Great Lakes species so was identified in error. Similarly, cases were found in which an upland species was selected instead of the correct wetland species with very similar characteristics; this was also a rare situation involving less than 10 species.

Collectively, these revisions reduced the plant data input list from 4192 species to 1724 species, a reduction of 59%, which should both speed up and reduce errors in data input.

Allison Kneisel reviewed and modified the existing non-native species list. This process resulted in the addition of 9 species to the non-native species list. For computation of the IBI scores, many of the best studied non-native species are used in computation of specific IBI metrics. For many of the species that were added to the non-native species list, there are few studies documenting what individual species are responding to, whether the response is to wetland dry down, increased nutrient loading, turbidity tolerance, etc.

A final thing to note about the wetland macrophyte IBI is that its values are likely being affected by the high water levels of the past few years. The macrophyte experts have noted that in many wetlands there seem to be fewer species than there were several years ago. Detailed analysis of the vegetation database could test this hypothesis.

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 14) 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.

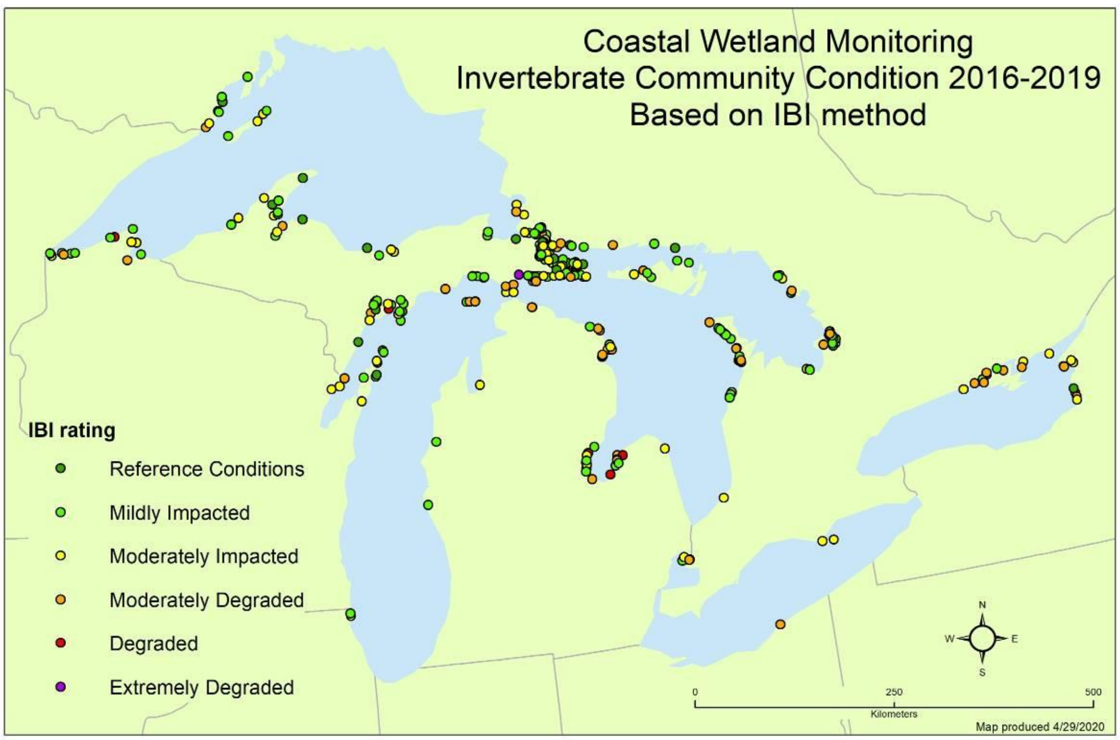

Figure 14. Condition of coastal wetland macroinvertebrate communties at sites with bulrush or wet meadow zones. Based primarily on data collected between 2016 through 2019.

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 15). 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.

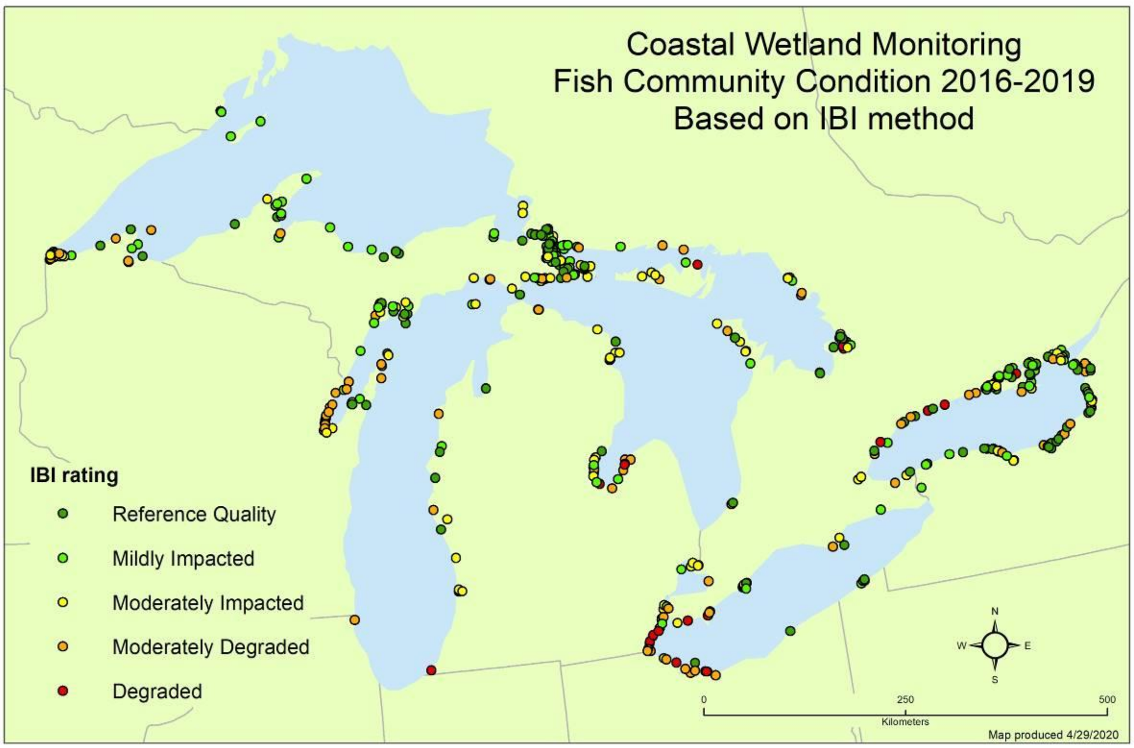

Figure 15. Condition of coastal wetland fish communties at sites with bulrush, cattail, lily, or submerged aquatic vegetation zones. Based primarily on data collected between 2016 through 2019.

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).

Bird indicators were calculated using the same approach described in previous years (Howe *et al.* 2007a, Howe *et al.* 2007b, Gnass Giese *et al.* 2015, Jung *et al.* 2020). In short, we applied a two-stage process: 1) quantify the responses of selected bird species to an *a priori* reference gradient based on a multivariate measure of disturbance or stress (the "human footprint"), and 2) use these parameterized biotic responses (BR functions) to iteratively assess the condition of wetlands according to the species present (or absent) in each wetland. The result for a given wetland site, called the Index of Ecological Condition (IEC), is scaled from 0 (worst condition) to 10 (best condition) in the context of all sites evaluated.

We refined the IEC method in two notable ways. Specifically, we used an improved reference gradient developed by Elliott *et al.* (in prep) and restricted the analysis to a suite of marsh-obligate or disturbance-associated species. Details of the analysis are provided in a manuscript that we will be submitting for publication in 2020. Jung *et al*. (2020) applied a similar approach in their recent application of the IEC in coastal wetlands of Lake Erie and Lake Michigan.

We quantified BR functions for 15 species or species groups (Table 15) that use non-woody coastal wetlands for nesting or foraging and are sensitive to the environmental reference gradient described above. Eight of these taxa consist of two or more ecologically similar species, and a ninth group combined three rare species (Northern Harrier, Black-crowned

Night-Heron, and Wilson's Snipe) that were not frequent enough to yield meaningful species-specific BR functions. One species, European Starling, is a non-native bird that uses wetlands occasionally in human-disturbed landscapes.

Table 15. Species and species groups used for calculation of Index of Ecological Condition (IEC) metrics.		
#	**Taxon**	**Species**
1	BITTERN	American Bittern (*Botaurus lentiginosus*) and Least Bittern (*Ixobrychus exilis*)
2	TERNS	Black Tern (*Chlidonias niger*), Common Tern (*Sterna hirundo*), and Forster's Tern (*Sterna forsteri*)
3	COYE	Common Yellowthroat (*Sterna forsteri*)
4	DABxMAL	Dabbling (marsh) ducks (*Anas* spp., *Mareca* spp., *Aix sponsa*), excluding Mallard (*Anas platyrhynchos*)
5	EAOS	Bald Eagle (*Haliaeetus leucocephalus*) and Osprey (*Pandion haliaetus*)
6	EUST	European Starling (*Sturnus vulgaris*)
7	GBH_GE	Great Blue Heron (*Ardea herodias*) and Great Egret (*Ardea alba*)
8	WREN	Marsh Wren (*Cistothorus* palustris) and Sedge Wren (*Cistothorus stellaris*)
9	MOOT	Common Gallinule (*Gallinula galeata*) and American Coot (*Fulica americana*)
10	PBGR	Pied-billed Grebe (*Podilymbus podiceps*)
11	RWBL	Red-winged Blackbird (*Agelaius phoeniceus*)
12	SACR	Sandhill Crane (*Grus canadensis*)
13	RAIL	Sora (*Porzana carolina*), Virginia Rail (*Rallus limicola*) , King Rail (*Rallus elegans*), and Yellow Rail (*Coturnicops noveboracensis*)
14	SWSP	Swamp Sparrow (*Melospiza georgiana*)
15	RARE	Rare/seldon recorded marsh obligates: Wilson's Snipe (*Gallinago delicata*), Northern Harrier (*Circus hudsonius*), Black-crowned Night Heron (*Nycticorax nycticorax*)

Geographic ranges of bird taxa used in our analyses extend across the Great Lakes basin, yet local abundances of these taxa are not evenly distributed. For example, large herons (Great Blue Heron and Great Egret) are much more frequent in the southern and eastern Great Lakes than in Lake Superior. Sedge Wrens are more frequent in the northern lakes. Combining species into multi-species groups (e.g., Sedge Wren + Marsh Wren = WREN; Least Bittern + American Bittern = BITTERN) mitigates the effects of some geographic patterns because at least one of the combined species can be expected in any given Great Lakes region. These combined groups enable us to validly compare IEC estimates across the basin.

Despite our efforts to develop a basin-wide IEC estimates, regional differences still are evident in the distributions of our selected taxa. We used Dufrene and Legendre’s (1997) indicator analysis to compare frequencies and abundances of the 15 taxa among 4 geographic regions:

Lake Ontario (LO), Lake Erie and southern Lakes Huron, and Michigan (LEsHM), northern Lakes Huron and Michigan (nLHM), and Lake Superior (LS). All but one taxon (EAOS = Bald Eagle/Osprey) showed a statistically significant affinity to one or more of these regions. For example, BITTERN, WREN, and DABxMAL were far more frequent in LO; EUST and GBH_GE were far more frequent in LEsHM; TERNS, SACR, RAIL, and RARE were far more frequent in nLHM; and COYE were significantly more frequent in LS (and nLHM).

In order to compare IEC values without the confounding effects of geographic differences in bird distributions, we applied a second approach. All 15 taxa were well represented in LEsHM and nLHM so we included the full list of species and species groups for these regions. However, we removed 2 seldom-encountered taxa (TERNS and SACR) from LO and 5 taxa (TERNS, DABxMAL, GBH_GE, MOOT, and PBGR) from the regional IEC analysis for LS. Results give a regional IEC that uses the same analytical framework but doesn't "penalize" geographic regions for taxa that are at the margins of their geographic distribution in the Great Lakes basin.

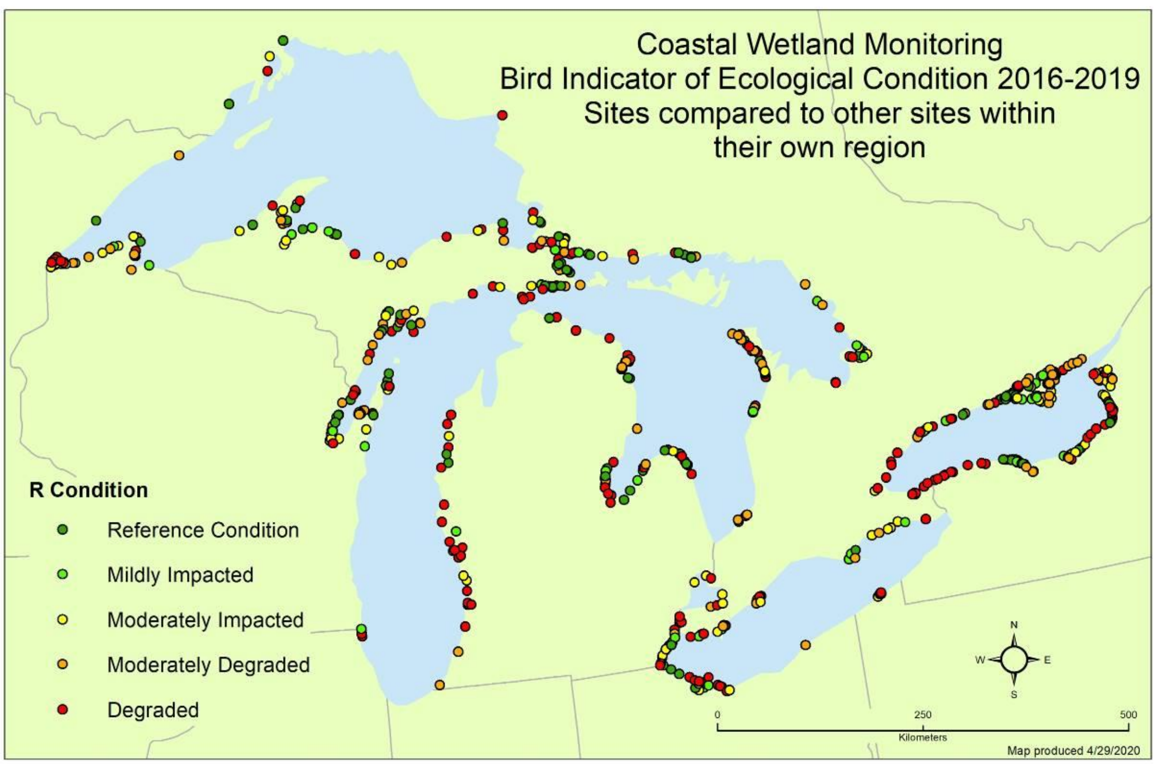

Figure 16. Condition of coastal wetland bird communties with wetlands compared regionally (see text for regions). This indicator is based on the IEC method using data collected primarily between 2016 and 2019.

Our results produced two alternative types of IEC values, 1) a basin-wide index (IECgl) using data from all 15 taxa and BR functions calculated from data representing all wetlands and 2) a regional index (IECr) that uses subsets of species for LS (10 taxa) and LO (13 taxa) and BR functions calculated within the respective regions (Figure 16). Unlike the reference gradient (C_{env}), the two alternative IEC values showed generally flatter or more skewed distributions, reflecting different patterns than those exhibited by the reference gradient. Note that high IEC values occur in all regions, suggesting that quality coastal wetlands (for birds) are widely distributed across the Great Lakes.

The most striking difference in the basin-wide vs. regional IEC values is the consistently higher values of IECr for LS, where excluded taxa (for IECr) are virtually absent in the regional sampling area. IECr values also were consistently higher than IECgl for Lake Erie (Figure 16).

Comparisons of IEC values over time suggest that changing water levels in Lakes Michigan, Huron, and Erie influence bird assemblages and the resulting ecological indicator metrics. Lowest IECr values invariably occurred during low water-level years of 2011-2014. Highest IEC values generally occurred during 2015-2019, but interesting local patterns are evident. Declining IEC values in Lake Michigan during 2018 and 2019 may be due to water levels being too high for optimal wetland bird habitat; indeed, some of the wetlands in Lake Michigan during 2019 were completely flooded and unavailable for wetland bird surveys. Temporal comparisons of IEC values also reveal a lower variability of IEC values for LO and LS, perhaps reflecting the different hydrologic regime affecting coastal wetlands in these lakes.

Recognizing that future work will be needed to expand and fortify our assessment of coastal wetlands, we submit the following general conclusions:

- High quality coastal wetlands exist in all 5 Great Lakes (Figure 16). Local concentrations of prime wetlands occur in areas like southern Lake Superior, Green Bay, Saginaw Bay, Sleeping Bear Dunes region of eastern Lake Michigan, Georgian Bay, western Lake Erie, northeastern Lake Ontario, etc., but opportunities for wetland protection and restoration are present across the Great Lakes coastal zone.
- Even in areas with concentrations of quality wetlands, a range of wetland conditions are evident. In other words, both degraded and high quality wetlands occur in most of the wetland "hot spots," again suggesting that restoration opportunities are widespread.
- Significant variation in wetland condition has occurred during the course of this investigation (2011-2019). Some of this variation can be attributed to historic changes in lake levels, which need to be taken into account when assessing the ecological condition of a given wetland site.
- Regional variations in biotic assemblages are unavoidable at the scale of the entire Great Lakes coastal zone, even if general taxa representing multiple species are used for indicator development. Biogeographic variation is likely relevant to the development of environmental indicators for other taxonomic groups besides birds.

- Wetland bird assemblages clearly are sensitive to local (wetland area), landscape (e.g., percent developed land within 2 km) and watershed level environmental variables. Some bird taxa are more sensitive than others, and the nature of the bird-environment relationship is often non-linear and certainly not identical among taxa. The Index of Ecological Condition (IEC) approach is able to account for these different types of responses. The resulting IEC values do not simply reflect the environmental variables, however. The value of this approach is this additional information that species can uniquely provide about the condition of Great Lakes coastal wetlands.

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 17). 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 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 ($p = 0.20$).

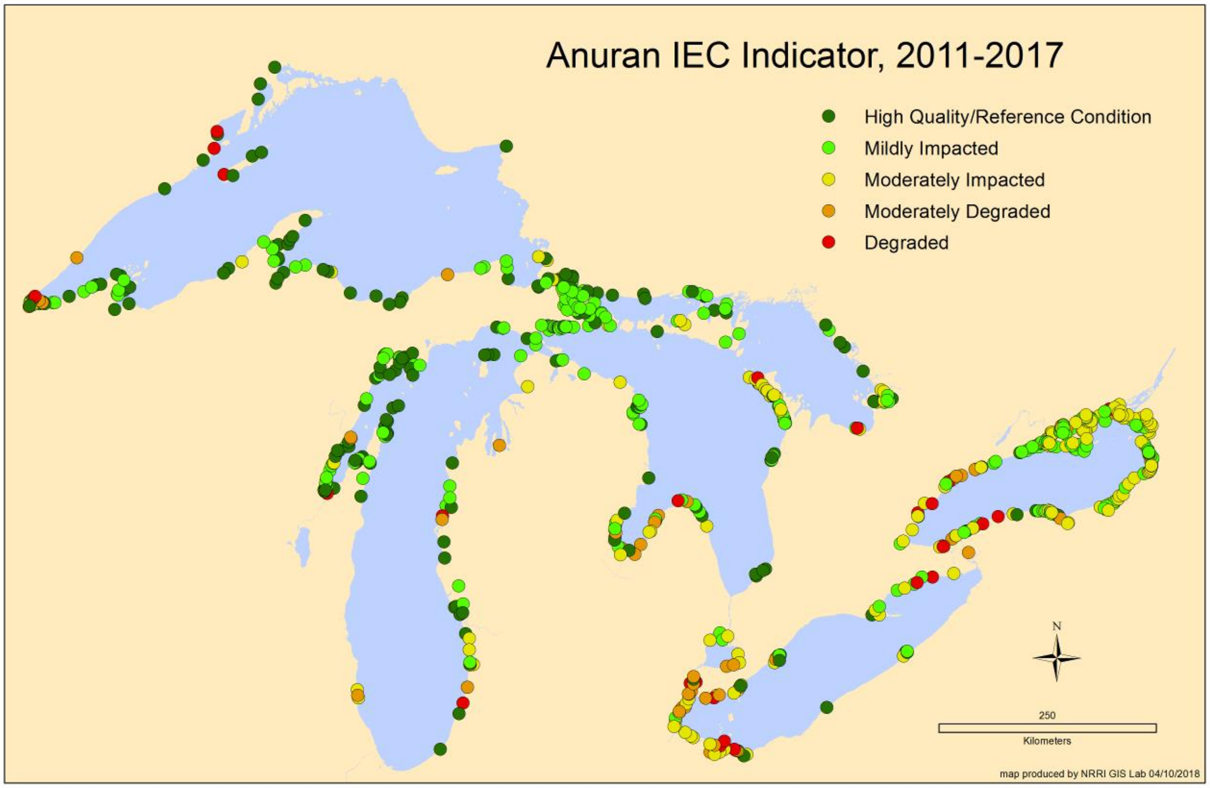

Figure 17. Condition of coastal wetland calling anuran communties. This indicator is based on the IEC method using data from 2011 through 2017.

Mean anuran species richness was highest in Lake Ontario during both low water ($\overline{x}$ = 4.12, SE = 0.10) and high water years ($\overline{x}$ = 4.65, SE = 0.13), while lowest mean species richness was recorded in Lake Erie (low water $\overline{x}$ = 2.66, SE = 0.11; high water $\overline{x}$ = 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 and 4 anuran species (Figure 18).

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)

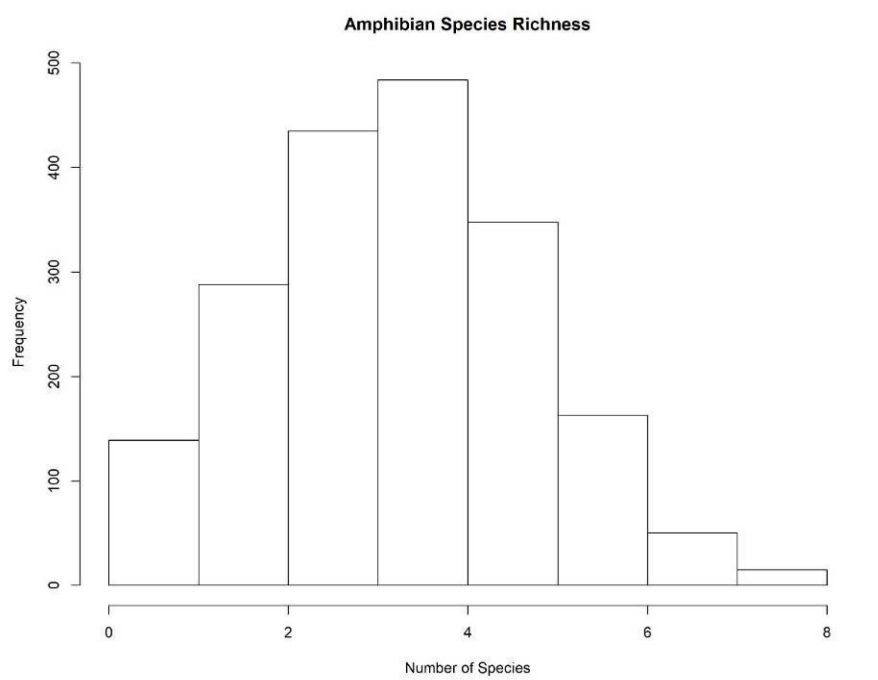

Figure 18. Distribution of anuran species richness at coastal wetland sample points from 2011-2017. Number of species refers to the total number of species recorded during three visits to the point during a given year.

Finally, we have developed a disturbance gradient (SumRank) indicator. 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 19).

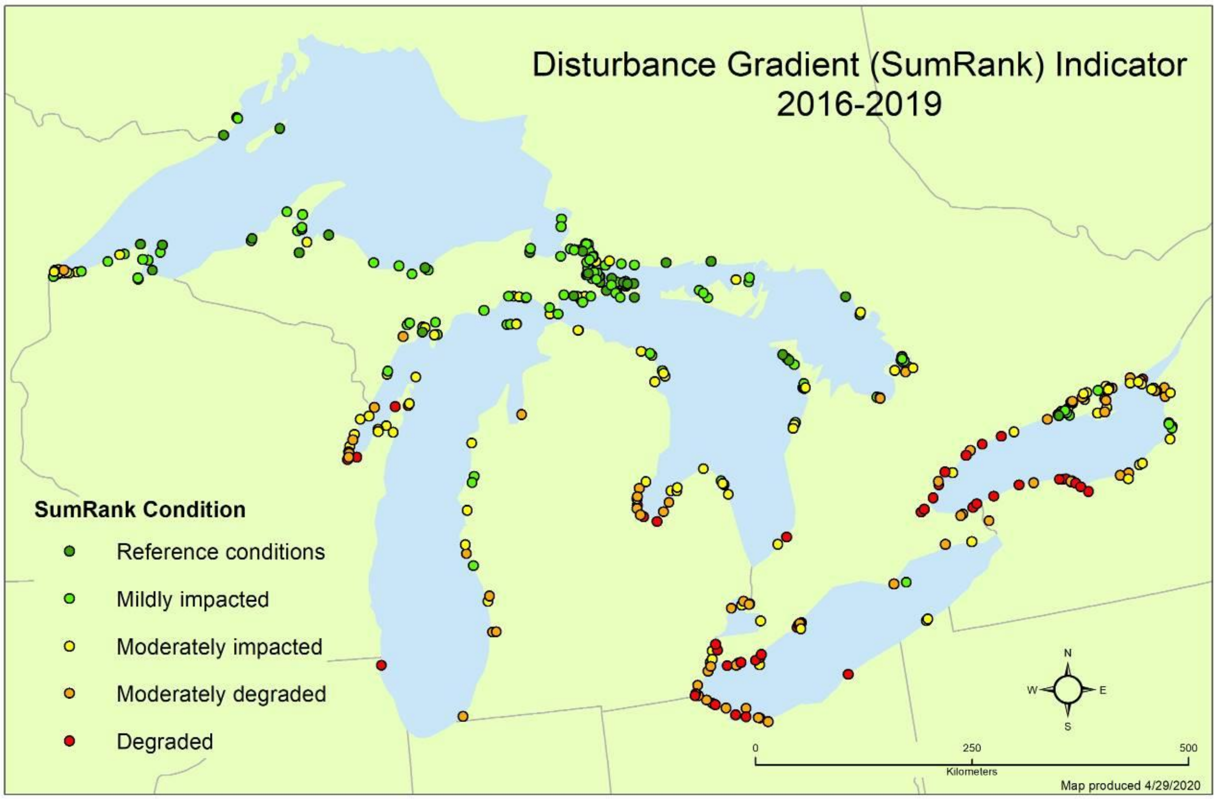

Figure 19. Disturbance gradient (SumRank) indicator. This indicator is based on landscape stressor data, site-based stressor data, and site water quality data. This is based primarily on data collected from 2016 through 2019.

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 was redeveloped and upgraded by LimnoTech and transitioned from an NRRI server to a permanent web hosting environment at Central Michigan University in spring 2016. 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, modifies and enhances the site as required to meet CWMP needs, as well as other end user needs.

Figure 20. 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;
- **Site Metrics ("Level 1")** – provides access to index of biological integrity (IBI) scores by wetland site via the coastal wetland mapping tool;
- **Agency/Manager (basic) ("Level 2")** - access to IBI scores and full species lists by wetland site via mapping tool;
- **Agency/Manager (data) ("Level 3")** - access to export tools for raw datasets (+ Level 2 capabilities);
- **CWMP Scientists ("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 site 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) and general monitoring observations for the site (e.g., hydrology, habitat, disturbances).

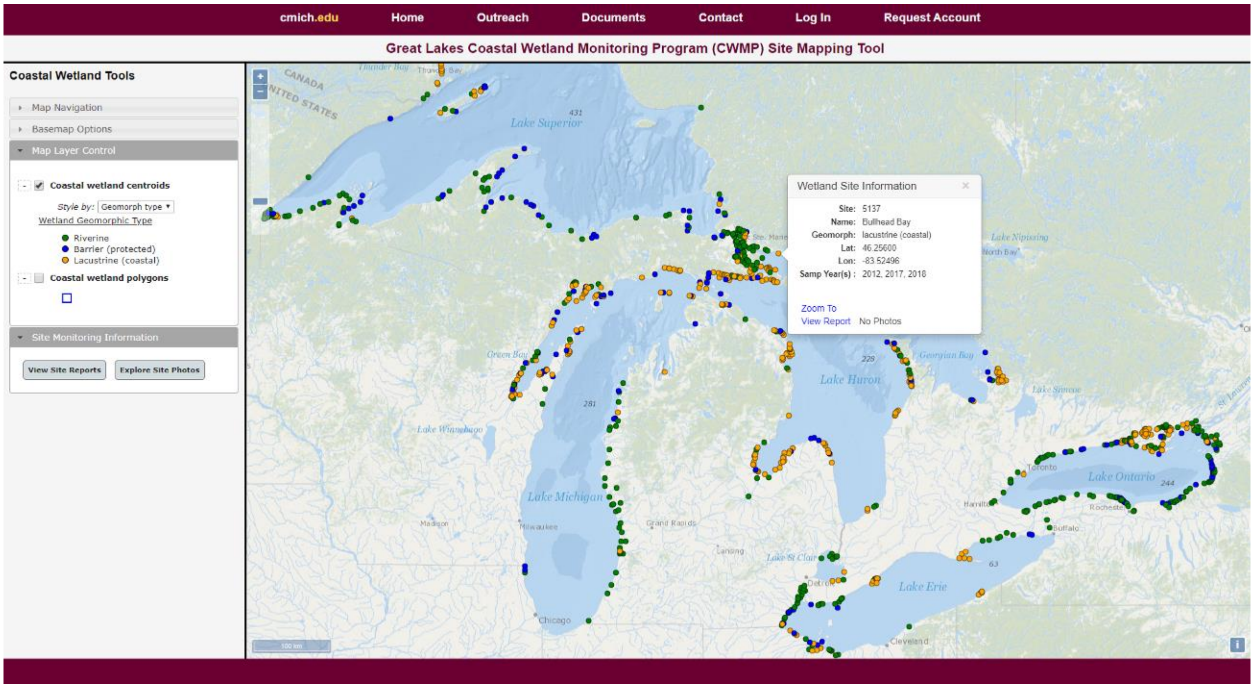

Figure 21. Coastal Wetland Mapping Tool – Public Version (geomorphic type view).

In addition to the features made available at the “Public” access level, users with “Level 1” (*Site Metrics*) access to the website can currently obtain information regarding IBI scores for vegetation, invertebrates, and fish; *Index of Ecological Condition* (IEC) scores for anurans and birds; and a *Disturbance Gradient* (“SumRank”) score representing water quality conditions.

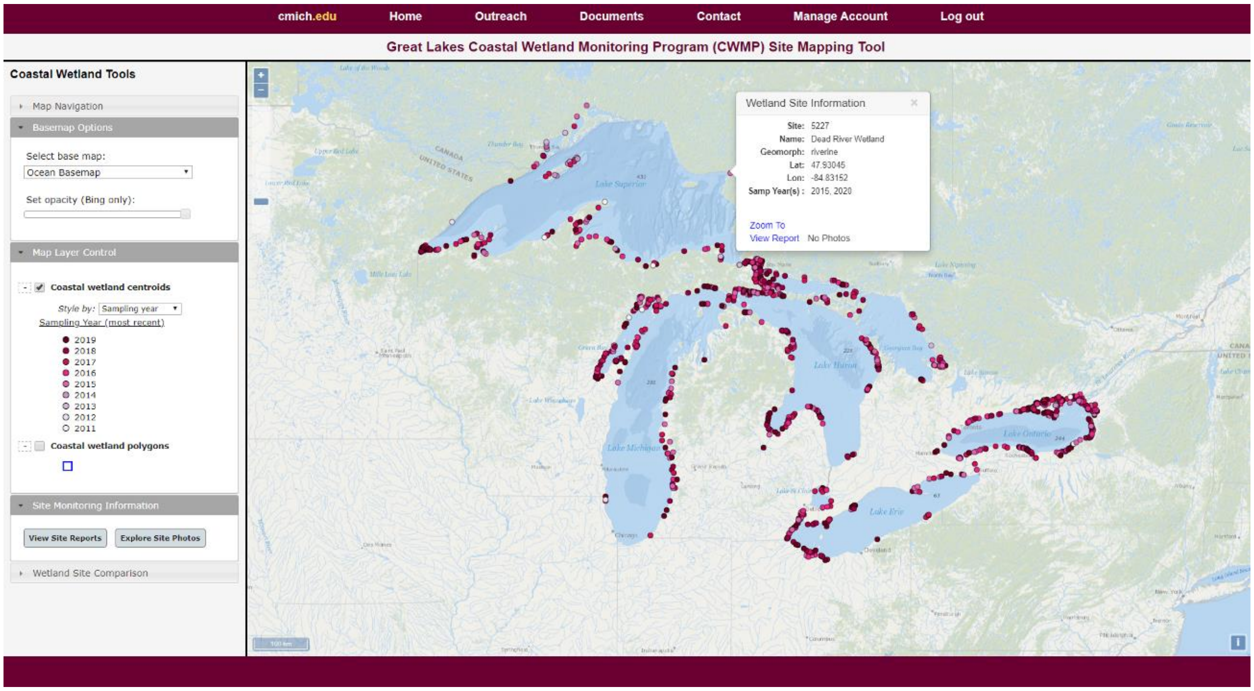

Figure 22. Coastal Wetland Mapping Tool – Public Version (sampling year view)

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 by:” pull-down menu (Figure 23). In addition, the actual IBI scores can be viewed by clicking on an individual wetland centroid.

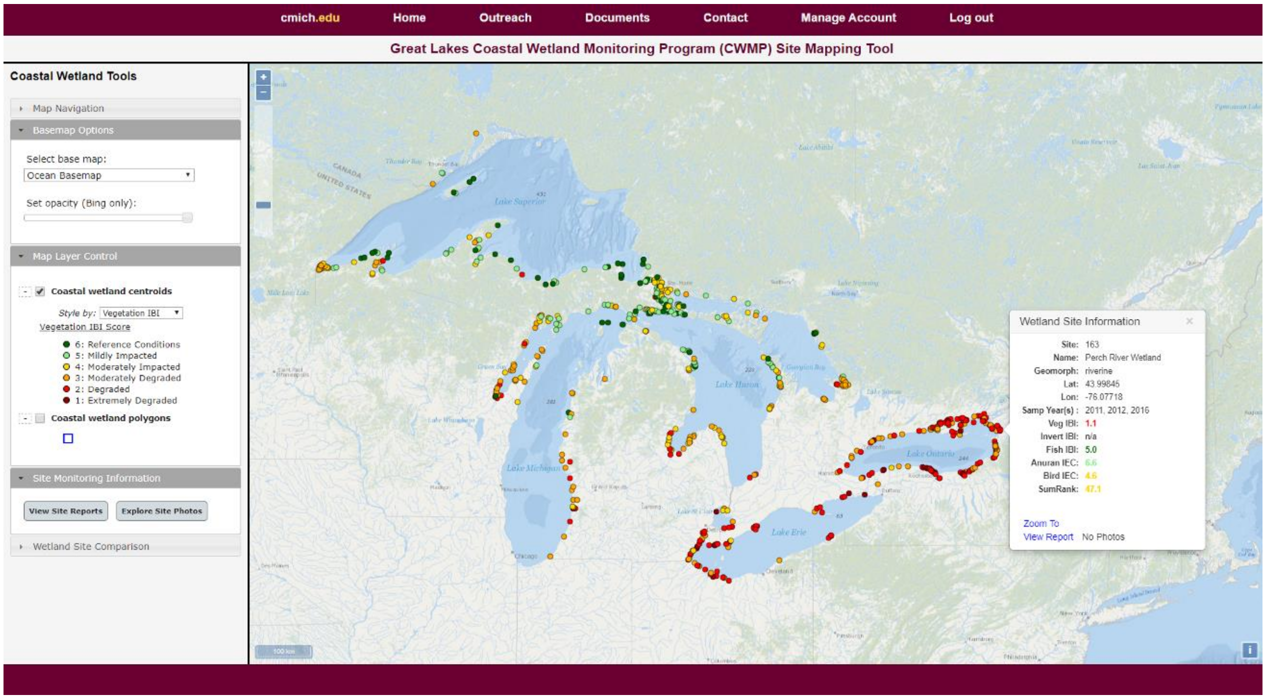

Figure 23. Coastal Wetland Mapping Tool with IBI scores displayed.

Users with “Level 2” (Agency/Manager (basic)) 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.

“Level 1” and “Level 2” users may also access the following tools that are available in the site mapping tool:

- **Wetland Site Report** – a tool that provides monitoring design information, monitoring observations, and the entire matrix of IBI/IEC/SumRank scores on an individual site basis.
- **Wetland Site Photos** – a photo viewer that allows users to review CWMP-approved digital photos taken during site sampling events.

- **Wetland Site Comparison** – a tool that allows users to select a geographic area of interest on the map and then generate a matrix comparing characteristics and IBI/IEC/SumRank scores across the selected sites.

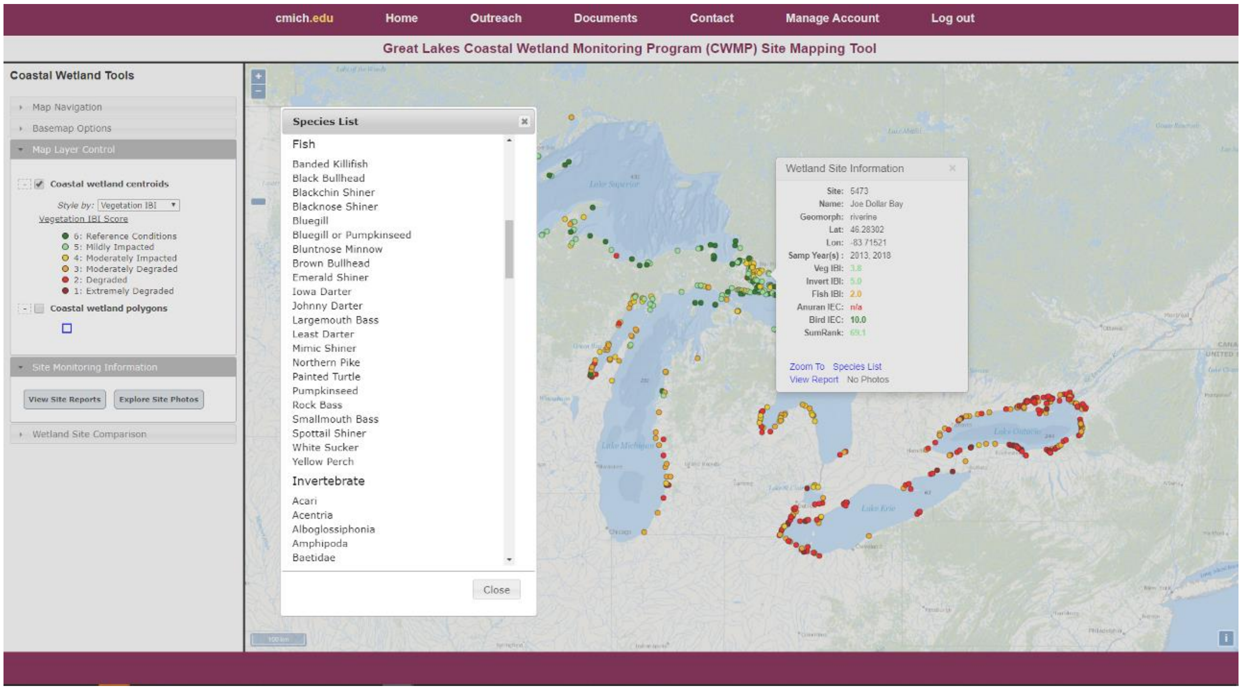

Figure 24. Coastal Wetland Mapping Tool with wetland macrophyte IBI scores and species list displayed.

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: Valerie Brady, Josh Dumke (Fish and Macroinvertebrates), Jerry Niemi, Annie Bracey (Birds and Anurans), Nicholas Danz (Vegetation), and Chris Filstrup (Water Quality)

2019 Sample Processing, Data Entry, and QC

All 2019 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.

Results from 2019

Anurans:
In 2019, a total of nine species were recorded throughout our study sites for a total of 528 individuals and 238 full choruses counted (Table 17). The average number of individuals recorded per site visit was 6. The average number of species detected per wetland was 4.2 with a minimum of two and a maximum of seven. There were only two sites with seven species

recorded, site 1068: Bark Bay Wetland, a barrier wetland on the south shore of Lake Superior near Herbster, WI and 1078: Nemadji River Wetland, a riverine wetland in Superior, WI.

Figure 25. Green frog at Pictured Rocks National Lakeshore

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

Table 17. List of anurans recorded during 2019 surveys.

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

Birds:

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

In the Western Great Lakes region there have been many observations of birds of special concern in the vicinity of the wetlands or using the wetland complexes in 2019 (Table 18). The most noteworthy observations included secretive marsh birds such as American Bittern (*Botaurus lentiginosus*), Least Bittern (*Ixobrychus exilis*), Virginia Rail (*Rallus limicola*), and Sora Rail (*Porzana carolina*). American Bittern were observed in five wetlands including two sites in Lake Superior, and three sites in northern Lake Huron. Least Bittern were observed at two sites in Lake Superior, one of which was in a site where restoration work has been done: Radio Tower Bay in the Duluth-Superior Harbor, MN. There were five sites where Virginia Rails were observed, two of which were in Lake Superior and three in northern Lake Huron. Sora rails were observed in eight wetlands; five sites in Lake Superior, one of which was in the restored site in Duluth-Superior harbor (Radio Tower Bay), and three sites in northern Lake Huron.

Figure 26. Common loon on nest

Eleven Bald eagles (*Haliaeetus leucocephalus*) were observed at 6 sites on Lake Superior, four of which were observed in the St. Louis River Estuary between Minnesota and Wisconsin, and two at restoration sites in the estuary (Dwights Point Wetland and Pokegama Bay Wetland #2). Additional species of interest include: Common Loon (*Gavia immer,* Figure 26), which were observed in 3 wetlands; Sandhill Crane (*Grus canadensis*) observed in 4 wetlands; and Common Tern (*Sterna hirundo*) observed at two wetlands within the St. Louis River Estuary.

Birds of special concern were observed in 23 of the 33 wetland sites surveyed in 2019 (Table 18). The lack of observations of Black Tern (*Chlidonias niger*) and Forster's Tern (*Sterna forsteri*), and the two observation of Common Tern (*Sterna hirundo*), all species of concern throughout the Great Lakes, is of particular interest and concern.

As in 2016 – 2018, the bird and anuran teams included additional vegetation sampling at each of the point count locations in 2019. We used the Great Lakes Marsh Monitoring Program's sampling protocol, modified to fit our sampling design, to collect these additional point-level vegetation data within a 100-m circle of each point-count location. Data were collected once at each location during the breeding season. We collected these samples later in the breeding season (during the second round of bird sampling) to insure growth was sufficient to properly estimate vegetation (type and abundance). Details regarding collection of this information can be found in the Great Lakes Marsh Monitoring Program's habitat guidance booklet (Meyer et al. 2006).

Table 18. List of birds of special interest recorded during 2019 surveys.

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

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.

Dr. Robert Howe of the University of Wisconsin, Green Bay continues to lead the bird and anuran metric and indicator calculation effort with input from the other Bird and Anuran co-investigators. He is pursuing a recalculation of the Index of Ecological Condition for breeding bird and anuran communities for sites that have been sampled since the inception of the CWM project. During the breakout session at the 2020 CWM annual meeting, Dr. Howe discussed how the environmental gradient has been updated with data that include a combination of habitat, landscape, geographic and climate variables for 840 coastal wetland sampling events throughout the Great Lakes. Dr. Howe also discussed some additional modifications that have been made to the analysie over the past year and he anticipates completing a manuscript that describes these methods and their results as they pertain to the CWM data sometime within the next year. Dr. Howe's group will initiate recalculations of the wetland gradient and begin exploring calculations of the Indicator of Ecological Condition. Another conference call will be planned post-2020 field season (September 2020) to discuss next steps and to identify a target journal for submission.

Fish and macroinvertebrates:

During summer of 2019 the NRRI field team visited 22 coastal wetlands of Great Lakes Superior (13 wetlands) and Michigan (9 wetlands) for the Great Lakes Coastal Wetland Monitoring Program. Wetlands were classified as barrier (n=7), lacustrine (n=4), and riverine (n=11). Seven sites were designated as benchmark sites, three were re-samples, and two sites (1478 and

1078) were considered “pre-sample” sites where habitat improvement work is planned for the near future. Data gathered at “pre-sample” sites will be important to determine future change at these wetlands following the completion restoration projects.

In 2019 we documented a new fish species to the Program in western Lake Michigan. For several years we have collected only Longnose Gar in the northern half of Green Bay and only Longnose x Shortnose Gar hybrids in the southern half of Green Bay, even though there is no physical barrier separating the two populations. In the summer of 2019 the NRRI crew captured our first Shortnose Gar at site 1444 (Figure 27), which is also the first Shortnose Gar documented in the Coastal Wetland Monitoring Program database. Dr. John Lyons (retired Department of Natural Resources biologist, and present Curator of Fishes at the University of Wisconsin) agreed with identifying this fish as Shortnose Gar, and added that while Longnose Gar x Shortnose Gar hybrids are much more common in Green Bay, Shortnose Gar are still present in very low abundance. Site 1444 has a lot of public litter that originates from a nearby highway overpass. The fish community at this site is largely comprised of species tolerant of degraded habitats with pollution and low oxygen, such as Common Carp, bullheads, and gar.

Figure 27. Shortnose Gar captured at site 1444 in 2019 by the NRRI field team, which is the first Shortnose Gar encountered in the Coastal Wetland Monitoring Program. Identification criteria include snout width-to-length ratio less than 6 and a lack of spots on the head and snout.

Water levels were still high in Lake Michigan compared to 6 years ago, and datasheet notes often referred to some zone types (e.g. lily and SAV) as being too deep to sample for fish. On the other hand, zones that typically are too shallow to fish were possible to sample with large fyke nets (e.g. wet meadow). Overall, 33 vegetation zones were sampled for invertebrates (SAV most prevalent), and 24 vegetation zones were sampled for fish (*Typha* most prevalent). We could not sample three wetlands during the summer of 2019: 1) site 1443 is located in a small bay and the inlet was blocked off with buoys and a barge as part of a contaminated sediments cleanup in the mouth of the Fox River, Green Bay; 2) site 1478 did not have any vegetation zones present as a result of high water levels in Lake Michigan, and 3) the wetland at site 1170 on the eastern side of Michigan's Keweenaw Peninsula in Lake Superior was completely filled in with "stamp sands" and no longer exists. The phenomenon observed at site 1170 is depicted in Figure 28. NRRI sampled a small part of the 1170 wetland that was still present in 2014, but by the summer of 2019 the remaining wetland became buried in stamp sands and there was nothing to sample (http://www.geo.mtu.edu/KeweenawGeoheritage/Lake/Gay_Sands.html).

Figure 28. Google Earth image from 2017 of stamp sands engulfing CWM site 1170. By 2019 the open water visible in this image had been buried by shifting stamp sands from Gay, MI.

The NRRI crew collected rusty crayfish only at site 1436 in the Lake Michigan basin (observed at 6% of fished sites). Crayfish are typical bycatch in fyke nets, and we encountered native crayfish species at 10 other locales (observed at 56% of fished sites). At site 1444 (where we captured the Shortnose Gar) we also observed invasive zebra mussels attached to a floating log, and curly-leaf pondweed collected while making d-net sweeps for invertebrates (Figure 29).

Figure 29. Aquatic invasive species observed at site 1444 in 2019: zebra mussels attached to a floating log (TOP), and curly-leaf pondweed collected in d-nets (BOTTOM).

Aquatic macrophytes:

In 2019 we again noted high water levels in wet meadow and emergent zones. One site (1040) was rejected because high water levels have severely flooded prior vegetation, which has subsequently been uprooted and washed away. We are noticing many alder thicket areas that border our wetlands have experienced substantial shrub die-backs associated with flooding. In many areas, these zones are transitioning back to wet meadow vegetation. For example in some cases *Carex lasiocarpa* is returning where it was not previously flourishing. In other areas, cattail monocultures and *Carex* sedge mats have been broken up, leading to open gaps and deeper watery depressions. In several sites in the St. Louis River estuary system, we have noticed expansion of cattail mats near the wetland edges where shrubs have died back. Wisconsin wetlands were found to have several rare plant taxa (Table 19) that have been reported to Wisconsin's Natural Heritage Inventory.

Table 19: Rare plants found in Great Lakes coastal wetlands in Wisconsin. This information was provided to the Wisconsin Department of Natural Resources Natural Heritage Inventory.

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

Other Activities

In 2012 the NRRI team retained some Black and Brown Bullheads from Coastal Wetland Monitoring Program fish surveys for an identification and genetics research project, which is now published (Dumke et. al., 2020). In addition, for several years Dumke had been in contact with retired fisheries biologists Dr. John Lyons about gar and gar hybrids captured during Coastal Wetland Monitoring Program surveys of Green Bay, WI wetlands. Dumke's photos and records of gar contributed to a publication in the American Midland Naturalist (Lyons and Sipiorski, 2020); Dumke is mentioned in the acknowledgments.

<u>Modeling of Bird Species of Conservation Concern in the Great Lakes Coastal Region</u>
Lisa Elliott, Dr. Niemi's graduate student successfully completed her Ph.D in the Conservation Sciences program at the University of Minnesota Twin Cities (Spring 2019). Lisa used the CWM bird data to model the distribution and abundance of several bird species that are of conservation concern in the Great Lakes and nationally. Lisa is currently revising two manuscripts associated with these data which all CMW Bird and Anuran co-investigators have had the opportunity to comment on and be included as co-authors. Lisa anticipates submitting both manuscripts to peer-reviewed journals by September 2020.

- Hierarchical modeling to identify habitat associations of wetland-obligate birds in Great Lakes coastal wetlands.
- Regional modeling of habitat associations for wetland-obligate birds in the Upper Midwest and Great Lakes basin.

Field Training

Birds and Anurans:
Due to work-related restrictions in travel associated with the COVID-19 pandemic, training for anuran surveys will be held virtually on 6 April 2020 and bird survey training will take place either in-person or virtually on 25 and 26 of May 2020. The latter is still dependent on restrictions by the state of Minnesota and the University of Minnesota. Negotiations and decisions by these respective administrations are currently on-going. Fortunately, all field personnel scheduled to conduct anuran and/or bird surveys in 2020 have surveyed on this project in previous years, so there are no new employees to train. 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 ensure 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 2020 have taken and passed each of the following tests on 1) anuran calls, 2) bird vocalization, and 3) bird visual identification that are based on an on-line system established at

the University of Wisconsin, Green Bay, prior to conducting surveys – see http://www.birdercertification.org/GreatLakesCoastal.

All 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 2020.

Fish, Macroinvertebrates, Vegetation, and Water Quality:
Fish, macroinvertebrate, vegetation, and water quality sampling training will be held in Duluth, Minnesota, and Superior, 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:
For 2020 a total of 57 sites have been selected to be surveyed by our western regional team for birds and anurans. Most of these sites have been sampled in previous years for at least one taxonomic group. All of the sites selected for sampling were reviewed to determine whether they were deemed safe and accessible to field crews. Of these 57 sites, we rejected 34 for anuran surveys and 29 for bird surveys. Seven of the 9 wetland sites on Isle Royale were rejected because 1) they were previously rejected as being unsafe to sample, not accessible, or the wetland did not meet sampling criteria (e.g., unsuitable). The remaining two sites were deemed infeasible to survey because the ferry service would not start early enough to get researchers there for the first anuran survey and at this time it is uncertain when the park will open and ferry service will actually resume. The remaining sites that were rejected (n = 20) were determined to be inaccessible either from site visits in previous years or were sampled in previous years and considered unsafe to sample again (e.g., anuran surveys which required boat or kayak access at night).

Therefore, of the 28 sites to be sampled for birds and 23 for anurans, 13 are wetland sites located in Ontario, Canada. Due to current travel restrictions between the U.S. and Canada because of COVID-19, it is unlikely that we will be able to sample the sites located in Canada this field season, at least not for anurans. If travel restrictions lift by June, we will plan to survey those 13 sites for birds. We are currently working with Doug Tozer's team in Canada to see if it is feasible for him to contract a qualified party to sample our sites for 2020. Of the 15 U.S. sites remaining, four are benchmark sites selected because they are of particular interest for restoration potential.

The locations of the sites that are scheduled to be sampled in 2020 by bird and anuran field crews stretch from the Duluth-Superior harbor area northeast along the north shore of Lake Superior as far as the Nipigon River, Ontario and eastward along the south shore of Lake Superior to the eastern end of the Upper Peninsula of Michigan as far as northeastern Lake Huron. Several sites scheduled to be surveyed in the Duluth-Superior harbor and one site at the Bad River Slough near Odanah, WI will require access by boat.

Fish, Macroinvertebrates, Vegetation and Water Quality:
NRRI maintains 4 core staff to supervise, coordinate and lead field teams during wetland surveys. 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 approximately 6 originally assigned to Central Basin crews. Presently, the NRRI team intends to visit 28 wetlands in 2020, but our ability to visit all sites will be contingent on COVID-19 travel restrictions this summer. For example, NRRI is assigned two sites in Canada near Thunder Bay; however, the Canadian border is presently closed to United States residents due to COVID-19. Within the United States we have ten wetlands in the Lake Superior basin, and 16 are within the Lake Michigan basin. The NRRI team will work within the recommendations and policies set forth by the Federal Government (e.g. Center for Disease Control) and University of Minnesota when conducting Coastal Wetland Monitoring Program field work during the COVID-19 pandemic.

Field sampling plans

Birds and Anurans:
Each of the coastal wetland sites scheduled to be surveyed this year will be visited a total of four times between April and July 2020. Anurans will be sampled three times at dusk during this period and birds will be surveyed twice. One of the two surveys for birds needs to occur in the morning, however, the other survey can occur either in the morning or in the evening (see revised Bird and Anuran SOP).

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 (2019)

Central Michigan University:
From October 1st, 2019 through March 31st, 2020, laboratory 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 laboratory QA/QC, which was completed in late March. All inconsistencies between sample identifications were discussed and taxonomists agreed on how to correctly identify these groups moving forward.

All 2019 plant data have been entered into the database and have been checked by crew leaders. Additionally, Dr. Albert has performed a final QA/QC check on all 2019 data. Dr. Albert, with the assistance of CMU and Brockport University staff, has modified the plant database entry list to streamline and speed up data entry.

100% of 2019 field data have been entered and checked by a second person. 100% of 2019 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 bird and anuran 2019 field survey data have been uploaded and QC'd in the database.

Lake Superior State University:
Data entry for all parameters, including water quality and benthic macroinvertebrates, has been completed and all data have been checked following the QA/QC procedures. We also completed a lab exchange of macroinvertebrate samples with NRRI and completed their samples in early March. LSSU samples were sent to NRRI for QA/QC in February and we are awaiting final ID, which was delayed due to NRRI closing in mid-March because of Covid-19.

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 2019 field season was completed in March 2020 (and those data were entered and checked for quality control in

late March 2020). 100% of the 2019 field data have been entered; 100% have been checked by a second person. 100% completion of macroinvertebrate identification for samples collected during the 2019 field season; 100% of 2019 macroinvertebrate data have been entered.

Macroinvertebrate sample exchange and QC with CMU was completed in March 2020. We are in the process of completing our annual DNR Collectors Permit report for fish sampling (for the 2019 field season), and Dr. Ruetz is in the process of applying for a scientific collector's permit to sample fish for the 2020 field season. Dr. Ruetz also is in the process of submitting our annual IACUC report for the 2019 field season.

University of Notre Dame:
Field-collected data (fish, habitat, water quality, etc.) and laboratory results (water chemistry, chlorophyll-*a*, etc.) have been entered and 100% QC'd. A total of 100% of 2019 macroinvertebrate samples have been identified, entered, and QC'd. Macroinvertebrate exchange with U Windsor took place in February 2020 at the CWMP meeting in Grand Rapids, MI. Identification of these macroinvertebrates is underway.

Analysis of 183 chlorophyll-*a* samples from Central Basin partners (CMU, GVSU, LSSU, UWN, CWS-ON [Environment and Climate Change 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.

Interesting results from 2019

Sampling crews noticed many impacts of high water levels including contracted and eroded vegetation zones (particularly wet meadows), the die-off or erosion of emergent species while submergent and floating species often increased in coverage, and the disruption of the typical pattern of zonation (Figure 30). Often zonation consisted of a small section of emergent or wet meadow vegetation behind a dead tree line separated from another larger patch of emergent vegetation by sections of open water or submerged vegetation. This loss of emergent vegetation was particularly characteristic of open lacustrine wetlands such as those along the north shore of Lake Huron or Lake Michigan. The thick organic material that forms in the wet meadow zone is particularly vulnerable to storm waves during extreme high water levels that occurred in 2019, resulting in intensive erosion of both the meadow vegetation and its roots, creating broad, deep mounds (wrack) of organic material along the shoreline. Additionally, at one site there was a large floating mat of dead *Typha* that appeared to have separated from the main stands of *Typha* along the shoreline, which may also be a result of increasing water levels. This same pattern was seen at research sites in Munuscong Bay along the St. Marys River.

Figure 30. Photographs looking out at transect three in Epoufette Bay (Site 1586) taken in 2017 (left) and 2019 (right). Pictures were taken within 10 m of each other, note the water level change and change in vegetation density.

Upon review of 2019 data, Dr. Albert noted that the invasive plant, European frogbit (*Hydrocharis morsus-ranae*) has increased dramatically in coverage at some Saginaw Bay and Lake Erie sites. This increase is not basin-wide but rather dependent upon specific site conditions. Another observation was that the width of the marsh vegetation has decreased dramatically at many exposed lacustrine wetlands along the north shore of Lakes Huron and Michigan, where high water levels have greatly increased wave erosion along the shoreline. A general observation is that overall plant diversity has also decreased at most sites, especially in the meadow zone, while submergent and floating plant diversity has increased at many sites due to more of the marsh being flooded. One submergent species in particular, *Zannichellia palustris*, was rarely recorded from 2011 to 2018, but was recorded at several sites in 2019.

2020 Field Season Preparations

Site Selection

Central Michigan University received the 2020 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 among crews, the central basin crew was assigned 47 sites. Site 5227 was rejected due to lack of access. Four of the remaining 46 sites were benchmark sites where ongoing restoration is taking place or is scheduled to occur. Of the 46 sites to be sampled in the summer of 2020, 21 were assigned to Central Michigan University, 7 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 mid-June at a Saginaw Bay site to ensure consistency and competency among crews.

Central Michigan University Aquatic Macrophytes:
Allison Kneisel will lead the 2020 vegetation surveys under the direction of Dr. Albert. Additional field crew leaders will be CMU staff member Matthew Sand who has two years of experience sampling vegetation with the CWMP and graduate student Olivia Anderson. Interviews for student assistant crew members are currently underway at Central Michigan University. Crew members will be trained in sampling protocol and plant identification in late June of 2020.

After trades, the central basin vegetation crew was assigned 48 sites, one which has been rejected due to lack of access (5227). Among the remaining sites there are five benchmark sites. Benchmark sites 7061 and 523 are part of long-term sampling efforts. Site 1598 is being sampled as monitoring for potential impacts of line 5 and sites 792 and 547 are being sampled to track impacts of high water levels.

CMU Fish, Macroinvertebrate and Habitat:
Student employees have been hired to help with field season preparations. In addition there are several returning crew members. Bridget Wheelock will be leading the

fish/macroinvertebrate/water quality crew. Bridget is supervising QA/QC, preparing reports, renewing permits and reviewing the QAPP, sites, and site access.

CMU Anurans and Birds:
Site selection for 2020 currently includes 57 wetland sites to survey for anurans and birds. Thirteen of those sites will not be sampled (10 are inaccessible, 2 are benchmarks not being sampled for birds and anurans, and 1 was rejected for lack of emergent vegetation). The remaining 44 sites are located in northern and eastern Lake Michigan, southern and western Lake Erie, and northern 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 the 16th of March, 2020. 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 2020, dependent on temperature and safety concerns. Training for bird surveys, procedures, and certification of bird identification will occur in April 2020, prior to sampling.

Lake Superior State University:
Dylan Loop will be returning to the crew as crew leader. The crew is planning a training session with CMU, GVSU, and Notre Dame in mid-June to ensure the crews' competency in all parts of the program. Reporting to the MDNR and Ontario MNR for the scientific collector's permit is underway as is the request for a 2020 scientific collector's permit.

Grand Valley State University:
Travis Ellens will serve as the field crew lead again for the GVSU crew in 2020. We are in the process of hiring two undergraduates as technicians to assist with sampling in the 2020 field season. The GVSU crew plans to visit the eight sites that were assigned for the 2020 field season. Sampling is planned for the weeks of June 22-26, June 29-July 2, and July 27-31. 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 2020 fieldwork.

University of Notre Dame:
Notre Dame has been assigned 7 sites to sample during the 2020 field season. These sites fall within the Lake Michigan basin. We anticipate sampling all sites between June and August 2020. We are in the process of obtaining scientific collector's permits from the states in which these lakes reside, and our IACUC has been renewed.

All UND core team members (PI Gary Lamberti, crew leader Sarah Klepinger, and grad student Whitney Conard) are staying up to date on developing plans for the summer 2020 season. For the upcoming season, we will hire two hourly summer field technicians. These technicians will be managed by the crew leader. To train new crew members, we plan to attend a June training session with other Central Basin crews, and also independently field test the protocols with our full crew.

Other Activities

A CMU postdoc, Anna Harrison, submitted a manuscript to *Wetlands* which has been accepted. It describes 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.

Harrison, A.M., A.J. Reisinger, M.J. Cooper, et al. 2019. A Basin-Wide Survey of Coastal Wetlands of the Laurentian Great Lakes: Development and Comparison of Water Quality Indices. *Wetlands.* https://doi.org/10.1007/s13157-019-01198-z

Two LSSU undergraduates completed their senior thesis projects and presented posters at the MI American Fisheries Society meeting using data from the GLCWM program. Derek Hartline looked at fish assemblage differences during low water (2011-12) and high water years (2019) in five wetlands and two vegetation zones. Dylan Loop evaluated the role of St. Marys River wetlands as nursery areas for young-of-year fishes using 2011-2019 data.

The paper by GVSU and NRRI on bullhead identification was published in the American Midland Naturalist:

Dumke, J.D., G.M. Chorak, C.R. Ruetz III, R.A. Thum, and J.N. Wesolek. 2020. Identification of Black Bullhead (*Ameiurus melas*) and Brown Bullhead (*A. nebulosus*) from the western Great Lakes: recommendations for small individuals. *American Midland Naturalist* 183:90-104.

Eastern U.S. Regional Team: **Douglas Wilcox and Katie Amatangelo (Vegetation), Chris Norment (Birds and Anurans), James Haynes and Matt Altenritter (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 2019 sampling. Dr. Michael Chislock and students in the limnology and water quality lab at The College at Brockport completed 100% of laboratory water quality analyses. Graduate and undergraduate technicians, overseen by Dr. Douglas Wilcox and Gregory Lawrence, entered and performed quality checks on all other data from the 2019 sampling season, including all bird, anuran, fish, water quality, and vegetation data.

2019 Benchmarks and Data Sharing

The College at Brockport continued to sample sites within the Rochester Embayment Area of Concern as benchmarks to aid in numerous restoration projects. Cranberry Pond was sampled as a benchmark site in 2019 to supplement pre-restoration monitoring for an upcoming National Fish and Wildlife Foundation funded restoration project carried out by National Audubon Society and Ducks Unlimited scheduled to break ground in winter 2020-21. This project aims to reduce invasive cattail (*Typha* spp.) cover and provide habitat for marsh birds and waterfowl, along with spawning areas for northern pike (*Esox lucius*). Braddock Bay was again sampled as a benchmark site in 2019 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) and Genesee Valley Audubon Society, by providing them with sightings and information on invasive plant and animal infestations. Reports of invasive species, particularly water chestnut (*Trapa natans*), led directly to these organizations' rapid response crews eradicating the infestations from the wetlands.

Working with Partners in 2019

The College at Brockport worked with several partners during 2019 on using CWMP sampling to assist local restoration projects. Data from fish, bird and anuran 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 provide post-restoration data on conditions at Braddock Bay to evaluate restoration success and guide adaptive management. Further, bird and anuran sampling at Cranberry Pond provided additional pre-restoration data for National Audubon Society that they can use in their pre-restoration evaluation at the site. CWMP data continue to assist Great Lakes Restoration Initiative-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, 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 GLCWMP 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 College at Brockport crews found a few individuals at sites in the Wolfe Island and Bay of Quinte regions this year.

2019 Observations

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

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

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

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

2020 Site List and Crew Assignments

The College at Brockport has finalized its 2020 site list and is beginning preparations to have the bird and anuran survey crews ready to sample within the next few weeks. Braddock Bay (7052), Cranberry Pond (50), and Black Creek Wetland (79) have received benchmark designations. Sampling at Braddock Bay will assist in post-restoration data collection for the GLRI-funded restoration project conducted by US Army Corps of Engineers. Sampling at Cranberry Pond will continue to provide pre-restoration data for a National Fish and Wildlife Foundation-funded restoration project carried out by National Audubon Society and Ducks Unlimited. Further, sampling at Black Creek (79) will help provide monitoring data at a potential reference site with similar wetland vegetation structure to that at Cranberry Pond. Further, it will provide baseline data for a future restoration project at the site.

The College at Brockport has worked with neighboring crews to swap sites and ensure as many sites are sampled across the basin as possible. Due to travel restrictions to Canada sites resulting from COVID-19 response guidelines, The College at Brockport received two sites in Ohio that will be sampled by fish, aquatic macroinvertebrate, water quality, and vegetation crews. No additional sites were picked up for the bird and anuran 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 anuran training is underway and both crew members passed the bird and anuran certification exams. College at Brockport personnel 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 (north shore of Lake Ontario – Water Quality, Fish, Macroinvertebrates, Vegetation)**

Sample Processing and Data Entry (2019)

All field data collected during the 2019 field season have been uploaded and QA'd. All fish, macroinvertebrate, macrophyte, and water quality data collected in 2019 were compiled and entered into the database and quality assured over the winter. Specimens have been exchanged with one of the two companion labs (part of the reciprocal exchange of macroinvertebrate specimens to ensure consistency of identification) and deferred with the other lab until the taxonomist returns from a leave of absence. All samples received have been identified and returned to the sample owners.

2019 Significant Observations:

Birds and Anurans:
Of note were 95 point occurrences of 9 Ontario bird species at risk (Table 20) based on information currently in the database. Also of note were 10 occurrences of Chorus Frog, which is listed as threatened in Canada (vs. 11 occurrences in 2018).

Table 20. Ontario bird species at risk observed in 2018 and 2019 sampling.

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

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

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

Fishes and Invertebrates

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

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

Notes on Water Levels and their Influence on Sampling

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

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

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

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

Reptiles
In Ontario, six turtle species occurring in the Great Lakes are listed as at risk under the *Species at Risk Act* (SARA): Spotted Turtle (*Clemmys guttata*) [Endangered]; Blanding's Turtle (*Emydoidea blandingii*) Great Lakes/St. Lawrence population; Spiny Softshell Turtle (*Apalone spinifera*) [Threatened]; and Eastern Musk Turtle (*Sternotherus odoratus*), Northern Map Turtle (*Graptemys geographica*) and Snapping Turtle (*Chelydra serpentina*) [Special Concern]. Under SARA, the Canadian Wildlife Service is responsible for developing a recovery strategy for endangered or threatened turtle species and a management plan for special concern turtle species. Critical habitat is a component of recovery strategies and under SARA critical habitat is defined as "the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species". The critical habitat may be based on the suitable habitat where turtles have been observed, including wetlands and watercourses (e.g., marshes, rivers, some lakes). Incidental observations from the Great Lakes Coastal Wetland Monitoring Program as well as other sources of turtle observations were used to identify many suitable habitat locations in Ontario as critical habitat. The data provided by CWMP were invaluable for critical habitat identification and continue to provide key information contributing to knowledge on abundance and distribution of all at risk turtle species.

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

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

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

Vegetation

Beginning in 2015, Great Lakes water levels have risen significantly after a prolonged period of low water. This has produced some significant new data patterns in that to some extent the water levels have changed more rapidly than has the distribution of the aquatic plants normally characteristic of particular depth zones. Furthermore, the sampling designs of macrophytes, invertebrates and fishes are all tied to the locations of zones and classes of emergent vegetation. Beginning In 2016 and continuing to the present, delineating between vegetation zones has sometimes become a challenge because species that normally are found in monoculture are becoming increasingly mixed with other species. Also, because many of the meadows were flooded, plants that one usually finds growing in the emergent and submergent zones were present deep in the meadow zone, and sedges and other meadow species could be found growing far out into what should be the emergent zone.

With record high lake levels again in 2019 we observed further thinning of some types of emergent vegetation. The gaps between meadow species and more flood-tolerant emergent species (cattails, bulrushes) were beginning to fill in with those other types of vegetation. However, high water continued to preclude fish sampling in many stands of bulrush and even cattail in many locations. However, at other sites we noted that cattail stands that had previously been too dense for us to penetrate now had large gaps which allowed us to get far enough into the zone to find water that was shallow enough to set fyke nets.

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

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

<u>Range expansions of Invasive Plant Species</u>

Nitellopsis obtusa

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

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

Phragmites

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

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

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

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

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

Trapa Natans

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

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

Field Training

Many of the individuals who will participate in fieldwork in 2020 were involved in sampling during the 2019 and earlier field seasons. Consequently, only refresher training will be undertaken for them. No new recruits will be joining the Tozer amphibian-and-bird team. Amphibian and bird surveys will be attempted at 58 sites. A warm, mild winter means that the onset of amphibian calling and mating will likely occur earlier than usual this year. Despite challenges posed by COVID-19, we are proceeding with bird and anuran surveys, since the 1 or 2-person crews are able to work safely with almost no interaction with other people.

Field crew members working with fishes, macroinvertebrates and water quality sampling will receive orientation during early May 2020 and are expected to conduct pilot sampling at local sites on Lake Erie during late May and early June. The Ohio sites that we would normally sample will be visited by a crew from SUNY Brockport. In exchange, we will sample an equivalent number of sites on Lake Ontario presently allocated to the Canadian Wildlife Service team. Three members of the 6-person Windsor field crew from 2019 will be involved in training and/or field work in 2020. They will train 1-2 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 2020: four staff with several years of field experience and training on the project and two co-op students (receiving training in June). 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.

High-water conditions have led the project PIs to make some revisions to our fish/invertebrate sampling options. Accordingly, all crew will be fully trained in these new options which include modifications of the criteria for selecting vegetation zones for sampling. Zone selection will be altered as follows. First, we are to collect invertebrate samples even in zones that exceed one-meter in depth, when possible. We began using these options in 2019, sampling on foot where possible. But where water was too deep to allow sampling on foot, we developed ways to safely sample from a boat. For this year, we will use D-nets with telescoping handles to enable more effective sampling from a boat. Second, if there are no zones under one-meter in depth, then we are to use a deep-set fishing method in one of the zones, meaning that the fyke nets will be fully submerged. We began trying this method in 2019, and will now incorporate deep-set methods into our training procedure. Thirdly, we are only expected to sample SAV zones if there are no other zones to sample. This new guideline was accompanied by discussion of minimum plant density required to count an SAV zone as being worth sampling. There are also minor modifications to vegetation sampling procedures under high-water conditions and these are being communicated to our vegetation specialist.

Four 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.

2020 Sites and Field Preparation

New sites for 2020 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 2020.

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 UW 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 2019 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 2020.

Danielle Gunsch (M.Sc 2020) 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 per day 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, sieche 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. Significant differences in abundance of some taxa (coenagrionid damselflies, *Gammarus* and *Hyalella* amphipods and flatworms) were observed among transects, particularly in North Channel wetlands. Nevertheless, multivariate analyses of community composition indicated that differences among wetlands were much greater than differences among locations along transects within wetlands. Joseph Gathman presented a summary of this work, as well as background information and previous research to provide context, at the annual meeting in February. Ultimately, this research is expected to provide new fish and benthic invertebrate measures sensitive to the effects of agricultural activity in wet meadow regions of wetlands.

During the summer of 2019, 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 2019, we continued 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 Onset Hobo water level loggers within wetland sites during the time that fyke nets were in place. Colleagues from other CWMP 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.

Water level loggers were deployed at 71 sites by 6 CWMP teams during their fish sampling periods in 2019 resulting in 84 records. Dissolved oxygen records were collected for 56 of those sample series. The data are expected to yield improved understanding of the factors contributing to variability in fish catches and help define the environmental suitability of areas for mobile fishes and the likelihood of capturing them.

In supplemental work, Nathan Tuck and assistants deployed water-level and dissolved-oxygen loggers for most of the sampling season in two Lake Erie wetlands. The team set fyke nets repeatedly over the summer, ensuring that both seiche and calm weather periods in each wetland were sampled to determine how water level and dissolved oxygen conditions influenced synoptic estimates of fish abundance and community composition. Nathan presented preliminary results from this work at the annual project meeting in February. Preliminary analysis confirms that wind action dramatically influences water quality parameters—particularly temperature and dissolved oxygen concentrations. Even in the absence of significant seiches, daytime winds brought cool, normoxic water into the wetland whereas night-time calm periods resulted in rapid anoxia as water flowed from shallow, emergent areas into the main wetland. Nathan is determining the extent to which these patterns influenced the numbers and species of fishes caught during a fyke net set.

Birds Canada combined bird and frog data from CWMP with data from the Great Lakes Marsh Monitoring Program to look at the effect of *Phragmites* control on these taxonomic groups. The results have been summarized in a peer-reviewed manuscript entitled, "Control of invasive *Phragmites* increases breeding marsh birds but not frogs," available here: http://cwbm.name/control-of-invasive-phragmites-increases-marsh-birds-but-not-frogs/. The study looked at changes in 1) species richness, 2) total abundance, and 3) occurrence of 9 breeding marsh bird species and 8 breeding marsh frog species before and after control of invasive *Phragmites*. It took place between 2011 and 2018 throughout 3 Great Lakes coastal wetland complexes located on Lake Huron and Lake Erie in southern Ontario. The study found at sample sites where invasive *Phragmites* was controlled that species richness of five breeding marsh bitterns and rails of conservation concern increased by 1.1 species, and that total abundance of these species combined increased significantly by 1.8 individuals.

By contrast, the study observed no change in these responses at nearby sample sites where no *Phragmites* control occurred. The study found no change in occurrence of any frog species or species richness or crude calling frequency of all frog species combined in relation to control of *Phragmites*, although the study lacked the ability to detect subtle changes in abundance of frogs, so more information would be helpful before firm conclusions can be made in relation to frogs and control of invasive *Phragmites* in the study system. The study shows that control of invasive *Phragmites* has a significant positive effect on breeding marsh bird species of conservation concern and suggests that continued effort to restore habitat for these species is warranted, particularly in areas where former breeding marsh bird biodiversity was high.

Building Interactions with Stakeholders and Collaborators

In 2019 we sampled Lake Pond on Point Pelee to provide Point Pelee National Park with pre-restoration baseline information prior to the implementation of a vegetation-removal exercise meant to reduce *Phragmites* and *Typha* encroachment and improve hydrological connectivity among several connected waterbodies. The breach created in summer 2018 between Lake Pond and the east shore of Lake Erie continues to permit water exchanges. These conditions persist, and we will expand our sampling on Point Pelee (sampling West Cranberry Pond) as requested by the PPNP staff. We will also sample nearby Hillman Marsh, which is under the jurisdiction of PPNP. Both Point Pelee and Hillman Marsh are designated as benchmark sites for 2020.

Coastal wetland information is continuing to be shared with the Detroit River Canadian Cleanup group (responsible for Canadian waters of the Detroit River Area of Concern): CWMP data on fishes, aquatic invertebrates, vegetation and water quality have been combined with other data collected by various consortia to determine criteria by which to delist several Beneficial Use Impairments. We compiled CWMP information from all available sites on Lake Erie and in the St. Clair-Detroit River system to determine if benchmarks in biological condition could be detected that could contribute to assessment of Impaired Uses #2 (Macroinvertebrates), #3 (fishes) and #11 (Aquatic Habitat). Preliminary analysis suggested 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. 2020).

We are working with Katrina Keeshig and Clint Jacobs of the NinDaWaabJig Heritage Centre at Bkejwanong Territory (Walpole Island First Nation) to gain access to Walpole Island First Nation, which is designated as a benchmark site for 2020. The "St. Clair River Delta" site (as named in the CWMP database) encompasses a very large area of wetland within the First Nation reserve. This large area of relatively unimpacted wetland has never been sampled by CWMP crew, so we are hopeful that our efforts to sample this site will provide data on some of the most pristine wetlands in the lower Great Lakes.

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. CWMP co-PIs have been asked to contribute their expertise 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 26 Canadian wetlands, most of which are part of the CWMP sampling program. We anticipate that there will be significant value added through continued cooperation on this important initiative.

As part of this new initiative, Environment and Climate Change Canada (ECCC) has been collaborating with Wikwemikong First Nation, Manitoulin Island, ON (Liaison - John Manitowabi). In 2018, we were able to arrange joint sampling of a new CWMP site, Whiskey Harbour Wetland (7071), and discussed collaboration to better assess wetland condition in First Nation areas of Manitoulin Island. In 2019, ECCC crews returned to sample vegetation and elevation for the GLPI project. We anticipate future collaboration with Wikwemikong First Nation and potentially returning to Whiskey Harbour for another year of CWMP sampling.

ASSESSMENT AND OVERSIGHT

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

For the second 5-year sampling rotation, no substantial methodological or quality assurance/quality control changes were necessary. The QAPP_r5 document was reviewed by project PIs prior to our February 19, 2016 project meeting. The only changes that were required to QAPP_r5 related to the data management system. Specifically, an update was added noting how the data management system developed by LimnoTech and housed at Central Michigan University will be backed up. Project PIs signed the updated QAPP (QAPP_CWMII_v1) at the February 19, 2016 meeting. This QAPP was reviewed and approved by all project co-PIs at our February 10, 2017 meeting and at our February 22, 2018 meeting. In thoroughly reviewing the QAPP and SOPs in early 2018, crews found inconsistencies between the QAPP and SOPs, requiring a handful of minor corrections and clarifications. PIs signed off on these changes at the 2018 PI meeting in Michigan in February. These fixes were incorporated into the QAPP in 2018 and PIs again signed off on the QAPP at the March 1, 2019, meeting in Michigan. The updated QAPP (QAPP_CWMII_rev 1) and SOPs were submitted to EPA in April of 2019. We have again identified some minor inconsistencies in the QAPP and SOPs that are being resolved for the next QAPP and SOP update.

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

- Training of all new laboratory staff responsible for macroinvertebrate sample processing: This training is conducted by experienced technicians at each regional lab and is overseen by the respective co-PI or resident macroinvertebrate expert. Those labs without such an expert send their new staff to the closest collaborating lab for training (e.g., LSSU sent a lead technician to NRRI or CMU for training). Macroinvertebrate IDers communicate with each other via their own email list and assist each other with difficult identifications and other questions that arise.

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

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

- Review of sites rejected after initial site visits: In cases where a site was rejected during a site visit, the reason for rejection was documented by the field crew in the site selection database. The project QA managers (Brady and Cooper) then reviewed these records to ensure consistency among crews. Occasionally, field crew leaders contacted Uzarski, Brady, or Cooper by cell phone when deciding whether to reject a site. The frequency of these consultations increased in 2018 and 2019 as high water levels made sampling particularly challenging.

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

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

- Collection of duplicate field samples: Precision and accuracy of many field-collected variables is being evaluated with duplicate samples. Duplicate water quality samples are collected at approximately every 10th vegetation zone sampled.

- QC checks for all data entered into the data management system (DMS): Every data point that is entered into the DMS is being checked to verify consistency between the primary record (e.g., field data sheet) and the database. QC should be complete for all data by the spring semi-annual report submission each year.

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

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

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

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

Example Water Quality QC Information

Laboratory Quality Assurances:

Water quality analyses from 2019 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 2019 have passed the criteria shown below (Table 21).

Table 21. Data acceptance criteria for water quality analyses.

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

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

Variability in Field Replicates:
An analysis of field duplicate variability for each year of the program is shown in Table 22. It is important to note that for many constituents, the variability within sample sets is related to the mean concentration, and as concentrations approach the method detection limit (MDL), the variability increases dramatically. A calculation of field replicate variability with values at or near the level of detection will often result in high RPDs. For example, if the chlorophyll measurements on a set of field duplicates are 0.8 µg/L and 0.3 µg/L, mean = 0.6, resulting in a RPD of 91% (RPD = [abs (rep a-rep b)/ (rep a+ rep b)/2)]*100, but since the MDL is ± 0.5 µg/L, this can be misleading.

The same can occur with analyte lab duplicates, and in these instances the QA officer 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 22 below lists average RPD values for each year of the project (2016-2019). Higher than expected average RPD values were associated with a preponderance of near detection limit values for ammonium, nitrate, and soluble reactive phosphorus (SRP), and high spatial variability for chlorophyll and turbidity. Other variables, such Total N, had values that were well above detection limit and low spatial variability; therefore, these values had much lower average RPD. Acceptance of data associated with higher-than-expected RPD was determined by the QA officers. The maximum expected RPD values are based on the MN Pollution Control Agency quality assurance project plan provided for the Event Based Sampling Program (http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/surface-water-financial-assistance/event-based-sampling-grants.html#for-grantees).

Table 22. Field duplicate sample variability for 2016-2019 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) minimum-maximum RPD.

Analyte	Maximum expected RPD	2016	2017	2018	2019
*Chlorophyll-a (µ/L)	30	31 (11) 0-105	47 (14) 0-130	37 (19) 0-161	55 (5) 2-200
Total phosphorus (mg/L)	30	27 (10) 0-163	26 (14) 0-91	25 (19) 0-95	10 (9) 0-42
**Soluble Reactive phosphorus (mg/L)	10	26 (11) 0-80	35 (14) 0-100	11 (19) 0-111	42 (9) 4.5-185
Total nitrogen (mg/L)	30	13 (11) 2-33	5 (14) 0.2-14	15 (19) 0-63	12 (9) 0.2-69
**NH4-N (mg/L)	10	45 (11) 0-131	43 (14) 0-137	36 (19) 0-113	45 (9) 0-135
**NO2/NO3-N (mg/L)	10	51 (11) 0-200	18 (14) 0-150	21 (19) 0-120	31.5 (9) 0.3-173
True color (Pt-Co Units)	10	6 (6) 0.4-18	5 (10) 0-20	6 (16) 0-28	2.4 (5) 0.5-5.8
Chloride (mg/L)	20	14 (8) 0-101	10 (12) 0.4-39	7 (19) 0-67	7.4 (7) 0-43

*Many of the chlorophyll field replicates were < 2 µg/L or 4 times the MDL.
**The variability between SRP, 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 tenth year (fifth field season of round 2). The lead PI, all co-PIs, and many technicians attended an organizational meeting in Grand Rapids, Michigan on February 14, 2020. The PIs discussed issues pertaining to the upcoming field season, dealing with high Great Lakes water levels, manuscript topics, and report products. We did not anticipate that Covid-19 would become a global pandemic just a few weeks later and so its effect on our work was not discussed.

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. Typically, most PIs 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. That will have to change this year due to Covid-19 requiring work using smaller crews that can maintain social distancing guidelines. However, most crews have returning and experienced personal, and the PIs will be in contact and do training and provide advice via phone calls and webinars. Under all circumstances, 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 are 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. Our challenge this final year is to ensure that we keep our crews and others safe from the spread of Covid-19 while doing our fieldwork. 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 not complacent about the lack of injuries and are grateful for 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.

LEVERAGED BENEFITS OF PROJECT (2010 – 2019)

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)

Investigating the Use of eDNA to Determine Fish Use of Otherwise Unsampleable Habitats: Some habitats cannot be sampled using fyke nets because of inappropriate water depth, unstable or unconsolidated bottom sediments or because that habitat is too fragile (e.g. wild rice). CoPI Valerie Brady with NRRI researcher Chan Lan Chun are investigating how well fyke net fish catches agree with fish eDNA collected from nearby benthic sediment to determine if eDNA could be used as a surrogate in situations where fish cannot be physically collected to determine habitat use.

Compiling and Assessing IBI and Environmental Stress Data to Assess Habitat Condition in the Detroit River Area of Concern (AOC): The Detroit River Canadian Clean-up (convened by Environment and Climate Change Canada and the Province of Ontario) is evaluating the weight of evidence with regard to delisting several Beneficial Use Impairments in the Detroit River AOC (Degradation of Fish and Wildlife, Degradation of Benthos, and Loss of Fish and Wildlife Habitat. However, years of monitoring and assessment have failed to demonstrate clear time trends in the condition of biota (aquatic vegetation, aquatic macroinvertebrates, fishes, birds) of the Detroit River's aquatic and riparian habitats. Attempts to evaluate indices of biotic integrity (IBIs) using the Reference Condition Approach (RCA) have been limited by an inability to achieve consensus on appropriate reference conditions. CoPIs Jan Ciborowski, Greg Grabas and Doug Tozer compiled land-based stressor data at the scale of second-order watersheds for the Detroit River AOC to let us assess how the IBI scores for sites in the Detroit River and adjacent areas (Lake Erie, Lake St. Clair, St. Clair River) vary as a function of environmental stress. We compiled all available biological monitoring datasets relating to aquatic vegetation, macroinvertebrates, fishes and birds within the study region and calculated composite measures of condition (IBIs) for each of the groups of biota and plotted the resulting scores against the stressor measures. We found provisional evidence of environmental stress thresholds for at least one IBI of each of the taxa investigated. Mapping the distribution of nondegraded vs. degraded watersheds for each of the biological groups will help the DRCC identify whether and where further remediation is necessary to allow delisting of the BUIs.

Minnesota Land Trust Natural Areas Project and Grassy Point Restoration: In 2018, the Minnesota Land Trust contracted a project with the Natural Resources Research Institute in Duluth, MN to conduct bird surveys along the St. Louis River Estuary (SLRE), within nine project areas that were nominated for inclusion in the Duluth Natural Areas Program (DNAP). This program was created in 2002 to manage Duluth's environmentally significant areas to ensure the preservation of services and values such as habitat diversity and water quality. In addition to data collected for this project, we also included breeding bird data collected by the CWMP at benchmark sites located within the SLRE that aligned spatially with the nine DNAP project areas. Collectively these data were used to determine if the proposed land parcels included in the nomination met the criteria of qualifying as an Important Bird Congregation Area (criteria included numeric thresholds for different guilds of species). Use of these data qualified all nine parcels as meeting the Important Bird Congregation Area criteria.

These data were then used in a spin-off project with Minnesota Land Trust, where bird communities were associated with spatially-explicit environmental and habitat variables to help guide conservation and management effort in the SLRE. In this project we were also able to identify habitat availability at the landscape-level to identify specific features that are under-represented in the SLRE but likely important to avian species (specifically wetland-dependent species). These analyses have been used to guide restoration plans at specific locations within the SLRE, including Grassy Point (a wetland located in a heavily industrialized area of the SLRE). Efforts to restore this wetland site are being developed by using the habitat requirements of wetland-dependent marsh bird species as a guide and restoration goal. The plans for Grassy Point are complete and on-the-ground restoration is scheduled to begin in the spring of 2020. NRRI CWMP teams will be involved in post-restoration monitoring of this site as well.

Deriving and Calibrating Environmental and Biological data for Lake Erie in Support of the Great Lakes Water Quality Agreement's Nearshore Framework: As part of the Annex 2 and Annex 7 plans of the revised GLWQA, Environment and Climate Change Canada (ECCC) and GLNPO began work to jointly develop an Integrated Nearshore Framework for the Great Lakes. The goal was to assemble scientific and technical recommendations for nearshore assessment. The assessment was expected to be used to set priorities and design an approach to identify areas of high quality for protection and areas under stress requiring restoration. ECCC and GLNPO convened several workshops beginning in 2014. In 2016, ECCC initiated a pilot project on the Canadian side of Lake Erie to come up with a workable methodology and approach to combining assessments of different condition measures. CWM coPIs Jan Ciborowski and Greg Grabas took part in a series of workshops and contributed information collected in part from CWM wetland surveys on Lake Erie. The first overall assessment of the nearshore in Lake Erie was reported in 2018. The weight of evidence indicated that there is a strong east to west gradient in nearshore condition with the highest quality habitat and biota observed in the eastern basin, and low quality in the western basin, influenced largely by seasonal occurrences of cyanobacteria. The nearshore of the Detroit River and Lake St. Clair was classified as being of moderate quality. Insufficient data were available to assess the St. Clair River. Assessments of the condition of coastal wetland across the study area were limited by variation in the types of data collected by different programs. A future goal will be to determine how best to align data collected from other programs with information collected using the CWM protcols.

Real-Time Logging of Water Level, DO, Light, and Wind to Assess Hydrological Conditions in Great Lakes Coastal Wetlands: The University of Windsor is coordinating a project to test the hypothesis that the numbers and species of fishes caught in wetland fyke nets are related to temporal variation in dissolved-oxygen (DO), and that such DO variation is partly driven by seiche activity causing temporary movement of cool, well-oxygenated lakewater into and out of wetlands. This variation in DO may be especially important in the densely vegetated, shoreline-associated wetland zones (usually wet meadow, under high-water conditions). An SOP document was developed in spring 2019 and circulated to all field crews.
Each field team has been encouraged to deploy water level and DO loggers at their fyke net sites over the course of the summer. In addition to providing important basic hydrological information about the condition of coastal wetlands, the resulting Great Lakes-wide dataset will be used to help account for variation in fish catches and ultimately improve the precision of fish IBI estimates. Preliminary data collected over the field season and suggestions for improvement will be discussed at the winter field meeting.

Bathymetry and mapping of wetlands in Point Pelee National Park during a period of hydrologic change: In 2018 Point Pelee National Park (PPNP) received approval through the Parks Canada Conservation and Restoration Project to begin a 4-year marsh restoration project. The project was focused 1) on increasing open water habitat and interspersion within the marsh and 2) reducing invasive vegetation. Members of the Ciborowski CWM team were asked if they would be able to conduct a preliminary survey of PPNP wetlands to determine the bottom profile and distribution of submerged aquatic vegetation. There was especial interest in the bathymetry of Lake Pond, whose eastern shoreline had been breached by wave action from Lake Erie during the summer as a consequence of the historically high water levels. In fall 2018 and during the 2019 field season, we conducted a benchmark survey of vegetation, aquatic invertebrates and water chemistry. We also assessed water depth, macrophyte distribution and cover and sediment characteristics throughout the wetland using the remotely-operated ROVER, which was developed for shallow-water data collection in remote locations. Water level and dissolved oxygen loggers set in place in the spring provided a full-season record of the frequency of seiches and associated changes in water quality. CWM researchers are anticipated to be involved as collaborators throughout the restoration project.

Inventory and distribution of zooplankton in coastal wetlands: As part of ongoing interest in assessing the condition of CWM wetlands we began assessing the community composition of zooplankton in the wetlands visited as part of the annual program. Pilot samples were first collectedin 2017. In 2018, zooplankton samples were collected at 16 Great Lakes coastal wetlands, situated off Manitoulin Island, northern Lake Huron, the western basin of Lake Erie, the Bruce Peninsula and Georgian Bay. In each wetland, samples were collected at 3 shallow-water points along a dissolved oxygen gradient. Records of water depth, substrate characteristics and vegetation density and composition were also tabulated. The sampling methods were based on techniques proposed by Lougheed and Chow-Fraser (2002) in developing their Zooplankton Quality Index. Seven Lake Huron wetlands were sampled in 2019.

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

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

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

Functional Indicators of Coastal Wetland Condition: Funded by the USGS through a Cooperative Ecosystem Studies Unit (CESU), this pilot project ran from fall 2016 through fall of 2019 to better determine functional indicators of Great Lakes coastal wetland usage by Great Lakes fish species. Sampling was done during the spring and fall at about 15 US wetlands already being assessed for CWM indicators during the summer. Data collected focus on fish usage of wetlands and the forage base for those fish, evaluated using macroinvertebrate sampling and examination of fish gut contents. Special emphasis was placed on determining usage of wetlands by young or spawning fish.

Conservation Assessment for Amphibians and Birds of the Great Lakes: Several members of the CWM project team have initiated an effort to examine the role that Great Lakes wetlands play in the conservation of amphibians and birds in North America. The Great Lakes have many large, intact freshwater wetlands in the interior portion of the North American continent. Their unique character, size, and plant composition supports populations of many species of amphibians and birds, many of which have been identified as endangered, threatened, or of special concern in North America. CWM PIs will use the extensive data that have been gathered by USEPA, such as the Great Lakes Environmental Indicators project and the Great Lakes Wetlands Consortium, as well as Bird Studies Canada, as critical input to this assessment. The initial stages in the development of the conservation assessment will be to analyze habitat and landscape characteristics associated with Great Lakes coastal wetlands that are important to wetland-obligate bird species occupying these habitats. By combining breeding bird data from the sources above and incorporating landscape variables, classification trees can be developed to predict presence and relative abundance of these species across the Great Lakes Basin. These methods, outlined in Hannah Panci's thesis; 'Habitat and landscape characteristics that influence Sedge Wren (*Cisthorus platensis*) and Marsh Wren (*C. palustris*) distribution and abundance in Great Lakes Coastal Wetlands'(University of Minnesota Duluth). She compiled data for over 800 wetlands in her analysis, which will provide a basis for analyzing additional wetland-obligate species.

Bird and Anuran Metrics and Indicator Calculations: Avian and anuran responses to landscape stressors can be used to inform land managers about the health of coastal wetlands and the landscape stressors that affect these systems (Howe et. al. 2007). Data that has been entered into the data management system and QC'd are being used to calculate some of the metrics and indicators for these wetlands.

Influence of broadcast timing and survey duration on marsh breeding bird point count results: Several members of the project team, with D. Tozer as lead, examined the importance of survey duration and timing of broadcast playbacks on occurrence and counts of wetland breeding birds. The results of this analysis suggest that 10-min point counts are superior to 15-min counts which have important implications for future monitoring and cost-effectiveness. These findings have been published in the journal of Avian Conservation and Ecology (Tozer et al. 2017).

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 were analyzed by Kettering University and their Swedish Biogas partner to determine the amount of methane that can be generated from this invasive. These samples was compared to their data set of agricultural crops, sewage sludge, and livestock waste that are currently used to commercially generate methane. Results demonstrated that hybrid cattail and reed canary grass both generated adequate levels of methane for use as feedstocks for biodigestion. The result of this and other CWM data collection are summarized in the Carson *et al.* 2018 journal article. The cattails-to-methane biofuels project is also funded (separately) by GLRI.

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

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

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

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

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

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

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

Developing a Decision Support System for Prioritizing Protection and Restoration of Great Lakes Coastal Wetlands: While a number of large coastal wetland restoration projects have been initiated in the Great Lakes, there remains little regional or basin-scale prioritization of restoration efforts. Until recently we lacked the data necessary for making systematic prioritization decisions for wetland protection and restoration. However, now that basin-wide coastal wetland monitoring data is available, development of a robust prioritization tool is possible and we propose to develop a new Decision Support System (DSS) to prioritize protection and restoration investments. This project, funded by the Upper Midwest and Great Lakes Landscape Conservation Cooperative, the Michigan Office of the Great Lakes, and the US Army Corp. of Engineers, has developed a DSS for wetlands along the US shoreline of the Great Lakes.

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

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

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

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

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

Lower Green Bay and Fox River AOC: Results from the Coastal Wetland Monitoring (CWM) Project and the Great Lakes Environmental Indicators (GLEI) Project are playing a central role in a $471,000 effort to establish fish and wildlife beneficial use impairment (BUI) removal targets for the Lower Green Bay and Fox River AOC (2015-2017) 1) Protocols for intensive sampling of bird, anurans, and emergent wetland plants in the project area have followed the exact methods used in the CWM project so that results will be directly comparable with sites elsewhere in the Great Lakes. 2) Data from GLEI on diatoms, plants, invertebrates, fish, birds, and anurans and from CWM on birds and anurans have been used to identify sensitive species that are known to occur in the AOC and have shown to be sensitive to environmental stressors elsewhere in the Great Lakes. These species have been compiled into a database of priority conservation targets. 3) Methods of quantifying environmental condition developed and refined in the GLEI and CWM projects are being used to assess current condition of the AOC (as well as specific sites within the AOC) and to set specific targets for the removal of two important BUIs (fish and wildlife populations and fish and wildlife habitats). 4. Application of the Index of Ecological Condition method (e.g., Howe et al. 2007) for measuring the condition of birds, anurans, and other fish and wildlife groups. Follow-up work was funded for 2018-2020 at $87,000 to continue refining field monitoring methods and metrics of 40 fish and wildlife habitats and populations.

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

Roxana Marsh Restoration (Lake Michigan): The University of Notre Dame (UND) team, led by graduate student Katherine O'Reilly and undergraduate Amelia McReynolds under the direction of project co-PI Gary Lamberti, leveraged the GLCWM monitoring project to do an assessment of recently-restored Roxana Marsh along the south shore of Lake Michigan. Roxana Marsh is a 10-ha coastal wetland located along the Grand Calumet River in northwestern Indiana. An EPA-led cleanup of the west branch of the Grand Calumet River AOC including the marsh was completed in 2012 and involved removing approximately 235,000 cubic yards of contaminated sediment and the reestablishment of native plants. Ms. McReynolds obtained a summer 2015 fellowship from the College of Science at UND to study the biological recovery of Roxana Marsh, during which several protocols from the GLCWM project were employed. During summer 2015 sampling of Roxana Marsh, an unexpected inhabitant of the Roxana Marsh was discovered -- the invasive oriental weatherfish (*Misgurnus anguillicaudatus*). Oriental weatherfish are native to southeast Asia and believed to have been introduced to the U.S. via the aquarium trade. Although there have been previous observations of *M. anguillicaudatus* in the river dating back to 2002, it had not been previously recorded in Roxana Marsh, and little information is available on its biological impacts there or elsewhere. We are currently using stable carbon and nitrogen isotopes, along with diet analysis, to determine the role of *M. anguillicaudatus* in the wetland food web and its potential for competition with native fauna for food or habitat resources. This discovery received media attention from the Illinois-Indiana Sea Grant College Program.

Chlorophyll-*a* Modeling: The UND team, in collaboration with Northland College and CMU, is investigating the drivers that influence chlorophyll-*a* in coastal wetlands. Along with CWM water data, we are utilizing GIS land use and connectivity data. Specifically, we seek to answer the following questions: (1) What variables best predict chlorophyll-*a* across the entire Great Lakes basin? (2) How do these variables change across each basin (i.e., Lake Michigan, Lake Erie, Lake Ontario, Lake Superior, Lake Huron)? (3) Are there differences in predictor variables across sub-basins (e.g., Lake Erie North vs. Lake Erie South)? (4) Does wetland type (lacustrine, riverine, or barrier) change chlorophyll-*a* predictors? (5) How do other potential variables, such as vegetation zone type or year, change chlorophyll-*a* predictors?

Invasion Vulnerability Index: The UND team, in collaboration with other CWM teams, aims to create a usable tool that predicts which aquatic invasive species from a list of 10 Great Lakes Aquatic Nuisance Species Information System (GLANSIS) watchlist species are of highest concern for prevention and early detection. We will combine Habitat Suitability Indexes (HSIs) made using wetland site-specific physio-chemical measurements and potential pathway data (distance to potential introduction pathways and distance to known established populations). Ultimately, we will produce an interactive, exploratory tool where a wetland can be selected, and a table will appear that shows the breakdown of invasion risk by species as invasion likelihood scores. If more information is desired about how the invasion likelihood score was calculated, an attribute table will display the numerical values for each criterion in the model. One of the main concerns with invasive species is how climate change will alter habitat suitability. To accommodate this concern, we will also include versions with future climate change scenarios using published IPCC environmental conditions. This information will be packaged together in an IVI for Great Lakes wetlands usable by scientists, managers, and the general public.

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

Hybridizing fish: In 2013 the NRRI field crew encountered gar around the Green Bay area of Lake Michigan which exhibited mixed morphological traits of shortnose and longnose species.

At that time, John Lyons at the Wisconsin Department of Natural Resources was working on a project to confirm hybrid individuals in the Fox River watershed (which drains into Green Bay, WI). Josh Dumke at NRRI contributed photos of gar captured in Green Bay during Coastal Wetland Monitoring fish surveys to John Lyons, and those contributions were acknowledged in a recently-published article: (Lyons, J., and J.T. Sipiorski. 2020. Possible large-scale hybridization and introgression between Longnose Gar (Lepisosteous osseus) and Shortnose Gar (Lepisosteous platostomus) in the Fox River drainage, Wisconsin. *American Midland Naturalist*, 183:105-115). In 2014 and 2015 Coastal Wetland Monitoring fish teams collected gar fin clips across the entire Great Lakes basin for a much more comprehensive look at species distributions and hybridization, but sample processing and analysis of those stored samples is dependent upon securing additional funds.

Management alternatives for hybrid cattail (*Typha x glauca*) 2011- 2014: Differing harvest regimes for hybrid cattail were evaluated at Cheboygan, Cedarville, and Munuscong Bay in northern Michigan with USEPA GLRI funding. At all of these sites plant data was collected by CWM and used as baseline data that was compared to control sites. Analyses demonstrated that during low-water conditions, native plant diversity was increased by harvest of hybrid cattail.

Impacts of hybrid cattail management on European frogbit (*Hydrocharis morsus-ranae*); This study, funded by MI DNR in 2016-2017 for research by Loyola Chicago and Oregon State University studied the response of European frogbit to cattail management, using CWM plant data collected in Munuscong Bay as baseline data. CWM data collected from 2011 to 2015 provided documentation of the expanding range of frogbit into the western Great Lakes. The study found that open, flooded stands of hybrid cattail provided important habitat for European frogbit, but that management to remove cattail was not effective for frogbit control.

Nutrient limitation in Great Lakes coastal wetlands: GLCWMP water quality data indicate that reactive nitrogen concentration is often much lower in wetland habitats than the adjacent Great Lake nearshore. With funding from Illinois-Indiana Sea Grant and the Wisconsin DNR we have evaluated the role of nitrogen limitation on benthic algal growth in wetlands throughout Lakes Michigan, Huron, and Superior.

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.

Coordination and Partnership with National Audubon: Per the agreement to share CWMP bird data with the National Audubon Society, we have provided data and guidance on appropriate use of these data for their project “Prioritizing coastal wetlands for marsh bird conservation in the U.S. Great Lakes”. The resulting manuscript from this project is currently in review with the journal ‘*Biological Conservation*’ and per the agreement all CWMP bird and anuran co-investigators have had the opportunity to contribute to the manuscript and be included as co-authors. We expect to maintain communications regarding any potential future use of the CWMP data by National Audubon and will continue to provide guidance on appropriate uses in future projects and analyses.

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

Requests for Assistance Collecting Monitoring Data

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

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

At some sites, restoration is still in the planning stages and restoration committees are interested in the data CWM can provide to help them create a restoration plan. This is happening in the St. Louis River AOC, in Sodus Bay, Lake Ontario, for the Rochester NY AOC, wetlands along Wisconsin's Lake Superior shoreline, and for the St. Marys River restoration in 2015 by tribal biologists at Sault Ste Marie.

Other groups have requested help sampling sites that are believed to be in very good condition (at least for their geographic location), or are among the last examples of their kind, and are on lists to be protected. These requests have come from The Nature Conservancy for Green Bay sites (they are developing a regional conservation strategy and attempting to protect the best remaining sites); the St. Louis River AOC delisting committee to provide target data for restoration work (i.e., what should a restored site "look" like); and the Wisconsin DNR Natural Heritage Inventory has requested assistance in looking for rare, endangered, and threatened species and habitats in all of the coastal wetlands along Wisconsin's Lake Superior coastline.

Southern Lake Michigan wetlands have mostly been lost, and only three remain that are truly coastal wetlands. CWM PIs are working with Illinois agencies and conservation groups to collaboratively and thoroughly sample one of these sites, and the results will be used to help manage all 3 sites.

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

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

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

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

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

Student Research Support

Graduate Research with Leveraged Funding:

- 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).
- Bird community response to changes in wetland extent and lake level 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)
- Per- and polyfluorinated alkyl substances (PFAS) in Great Lakes food webs and sportfish (University of Notre Dame)

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 presented at the International Association for Great Lakes Research annual meeting).
- 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). Several presentations at regional meetings and IAGLR.
- Non-native fish use of Great Lakes coastal wetlands (Northland College funding). Poster presentations by Northland College students at Wisconsin Wetland Science Meeting and IAGLR.

Graduate Research without Leveraged Funding:

- Impacts of drainage outlets on Great Lakes coastal wetlands (Central Michigan University).
- Effects of anthropogenic disturbance affecting coastal wetland vegetation (Central Michigan University).
- Great Lakes coastal wetland seed banks: what drives compositional change? (Central Michigan University).
- Spatial scale variation in patterns and mechanisms driving fish diversity in Great Lakes coastal wetlands (Central Michigan University).
- Building a model of macroinvertebrate functional feeding group community through zone succession: Does the River Continuum Concept apply to Great Lakes coastal wetlands? (Central Michigan University).

- Chemical and physical habitat variation within Great Lakes coastal wetlands; the importance of hydrology and dominant plant zonation (Central Michigan University)
- Macroinvertebrate-based Index of Biotic Integrity for Great Lakes coastal wetlands (Central Michigan University)
- Habitat conditions and invertebrate communities of Great Lakes coastal habitats dominated by Wet Meadow, and *Phragmites australis*: implications of macrophyte structure changes (Central Michigan University)
- The establishment of *Bithynia tentaculata* in coastal wetlands of the Great Lakes (Central Michigan University)
- Environmental covariates as predictors of anuran distribution in Great Lakes coastal wetlands (Central Michigan University)
- Impacts of muskrat herbivory in Great Lakes coastal wetlands (Central Michigan University).
- Mute swan interactions with native waterfowl in Great Lakes coastal wetlands (Central Michigan University).
- Effects of turbidity regimes on fish and macroinvertebrate community structure in coastal wetlands (Lake Superior State University and Oakland University).
- Scale dependence of dispersal limitation and environmental species sorting in Great Lakes wetland invertebrate meta-communities (University of Notre Dame).
- Spatial and temporal trends in invertebrate communities of Great Lakes coastal wetlands, with emphasis on Saginaw Bay of Lake Huron (University of Notre Dame).
- Model building and a comparison of the factors influencing sedge and marsh wren populations in Great Lakes coastal wetlands (University of Minnesota Duluth).
- The effect of urbanization on the stopover ecology of Neotropical migrant songbirds on the western shore of Lake Michigan (University of Minnesota Duluth).
- Assessing the role of nutrients and watershed features in cattail invasion (*Typha angustifolia* and *Typha* x *glauca*) in Lake Ontario wetlands (The College at Brockport).
- Developing captive breeding methods for bowfin (*Amia calva*) (The College at Brockport).
- Water chestnut (*Trap natans*) growth and management in Lake Ontario coastal wetlands (The College at Brockport).
- Functional diversity and temporal variation of migratory land bird assemblages in lower Green Bay (University of Wisconsin-Green Bay).
- Effects of invasive *Phragmites* on stopover habitat for migratory shorebirds in lower Green Bay, Lake Michigan (University of Wisconsin-Green Bay).

- Plant species associations and assemblages for the whole Great Lakes, developed through unconstrained ordination analyses (Oregon State University).
- Genetic barcoding to identify black and brown bullheads (Grand Valley State University).
- Coastal wetland – nearshore linkages in Lake Michigan for sustaining sport fishes (University of Notre Dame)
- Anthropogenic disturbance effects on bird and anuran communities in Lake Ontario coastal wetlands (The College at Brockport)
- A fish-based index of biotic integrity for Lake Ontario coastal wetlands (The College at Brockport)
- Modeling potential nutria habitat in Great Lakes coastal wetlands (Central Michigan University)
- Modeling of Eurasian ruffe (*Gymnocephalus cernua*) habitat preferences to predict future invasions (University of Minnesota Duluth in collaboration with USEPA MED)
- Modeling species-specific habitat associations of Great Lakes coastal wetland birds (University of Minnesota)
- The effect of urbanization on the stopover ecology of Neotropical migrant songbirds on the western shore of Lake Michigan (University of Minnesota Duluth).
- Nutrient limitation in Great Lakes coastal wetlands: gradients and their influence (Central Michigan University; with additional funding from the CMU College of Science and Engineering)
- Invasive *Phragmites australis* management (Central Michigan University; with additional funding from the CMU College of Science and Technology)
- The relationship between vegetation and ice formation in Great Lakes coastal wetlands (Central Michigan University; with additional funding from CMU College of Science and Engineering)
- PFAS accumulation by Dressenidae *spp* in Great Lakes Coastal Wetlands (Central Michigan University)
- Development of a vegetation based IBI for Great Lakes Coastal Wetlands (Central Michigan University)
- Development of a model for Great-Lakes wide invasive plant harvest for bioenergy production and nutrient recycling (Loyola Chicago and Oregon State 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; Published in *Ecosphere*).
- 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, complete).
- Water depth-related variation in net ecosystem production in a Great Lakes coastal wet meadow (University of Windsor, complete).
- 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).

- Coastal wetlands as nursery habitat for young-of-year fishes in the St. Marys River (Lake Superior State University; presented at MI American Fisheries Society annual meeting)

- Relationship between water level and fish assemblage structure in St. Marys River coastal wetlands (Lake Superior State University; presented at MI American Fisheries Society annual meeting)

- Dominance patterns in macroinvertebrate communities in Great Lakes coastal wetlands: does environmental stress lead to uneven community structure? Northland College.

Jobs Created/Retained (cumulative since 2011):

- Principal Investigators (partial support): 20 (average per year)
- Post-doctoral researchers (partial support; cumulative): 5
- Total graduate students supported on project (part-time; cumulative): 103
- Unpaid undergraduate internship (summer, cumulative): 35
- Undergraduate students (paid; summer and/or part-time; cumulative): 173
- Technicians, jr. scientists (summer and/or partial support; cumulative): 129
- Volunteers (cumulative): 47

Total jobs at least partially supported: about 430.
Students and young scientists trained: 445.

Presentations about the Coastal Wetland Monitoring Project (inception through 2019)

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.

Bergen, E., E. Shively, M.J. Cooper. Non-native fish species richness and distributions in Great Lakes coastal wetlands. International Association for Great Lakes Research Annual Conference, June 10-14, 2019, Brockport, NY. (poster)

Bergen, E., E. Shively, M.J. Cooper. Drivers of non-native fish species richness and distribution in the Laurentian Great Lakes. February 19-21, 2019. Madison, WI. (poster)

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.

Brady, V., G. Niemi, J. Dumke, H. Wellard Kelly, M. Cooper, N. Danz, R. Howe. 2019. The role of monitoring data in coastal wetland restoration: Case studies from Duluth and Green Bay. International Association of Great Lakes Research Annual Meeting, Brockport, NY, June 2019. Invited oral presentation.

Buckley, J.D., and J.J.H. Ciborowski. 2013. A comparison of fish indices of biological condition at Great Lakes coastal margins. 66th Canadian Conference for Freshwater Fisheries Research, Windsor, ON, January 3-5 2013. Poster 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.. Nutrient limitation in wetland ecosystems. Wisconsin Department of Natural Resources, February 12, 2016, Rhinelander, WI.

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.. Monitoring biotic and abiotic conditions in Great Lakes coastal wetlands. Wisconsin DNR Annual Surface Water Quality Conference. May 2016, Tomahawk, WI.

Cooper, M.J. The Depth of Wisconsin's Water Resources. Panel Discussion, Wisconsin History Tour, Northern Great Lakes Visitors Center, June 15, 2016, Ashland, WI.

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

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., T.M. Redder, C. Hippensteel, V.J. Brady, D.G. Uzarski. Developing a decision support tool to guide restoration and protection of Great Lakes coastal wetlands. Midwest Fish and Wildlife Conference, Feb. 5-8, 2017, Lincoln, NE.

Cooper, M.J., T.M. Redder, V.J. Brady, D.G. Uzarski. Developing a decision support tool to guide restoration and protection of Great Lakes coastal wetlands. Wisconsin Wetlands Association Annual Conference, February 28-March 2, 2017, Steven's Point, WI.

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., 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. Gar
wood. Great Lakes Coastal Wetland Monitoring." Webinar hosted by Michigan Department of Environmental Quality, April 14, 2017. 78 attendees.

Cooper, M.J., A. Hefko, M. Wheeler. Nitrogen limitation of Lake Superior coastal wetlands. Society for Freshwater Science Annual Conference, May 20-24, 2018, Detroit, MI.

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

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

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

Cooper, M.J., T.M. Redder, V.J. Brady, D.G. Uzarski. A data visualization tool to support protection and restoration of Great Lakes coastal wetlands. International Association for Great Lakes Research Annual Conference, June 10-14, 2019, Brockport, NY

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.

Gathman, J.P., J.J.J. Ciborowski, G. Grabas, V. Brady, and K.E. Kovalenko. 2013. Great Lakes Coastal Wetland Monitoring project: progress report for Canada. 66th Canadian Conference for Freshwater Fisheries Research, Windsor, ON, January 3-5, 2013. Poster Presentation.

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.

Gunsch, D., J.P. Gathman, and J.J.H. Ciborowski . 2018. Variation in dissolved-oxygen profiles along a depth gradient in Lake Huron coastal wet meadows relative to vegetation density and agricultural stress over 24 hours. IAGLR Conference, Toronto, Canada. Poster Presentation. 18-22 June 2018.

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.

Hefko, A.G., M. Wheeler, M.J. Cooper. Nitrogen limitation of algal biofilms in Lake Superior coastal wetlands. International Association for Great Lakes Research Annual Conference, June 10-14, 2019, Brockport, NY. (poster)

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.

Hohman, T., B. Howe, E. Giese, A. Wolf, and D. Tozer. 2019. Bird Community Response to Changes in Wetland Extent and Interspersion in Great Lakes Coastal Wetlands. Heckrodt Birding Club Meeting, Menasha, Wisconsin. Oral Presentation. 6 August 2019.

Hohman, T.R., R.W. Howe, A.T. Wolf, E.E.Gnass Giese, D.C. Tozer, T.M. Gehring, G.P. Grabas, G.J. Niemi, and C.J. Norment. 2019. Bird Community Response to Changes in Wetland Extent and Interspersion in Great Lakes Coastal Wetlands. Presented at the 62nd Annual Meeting of the International Association of Great Lakes Research (IAGLR), 12 June 2019, Brockport, NY.

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, B., E. Giese, A. Wolf, and B. Kupsky. 2019. Restoration Targets for Great Lakes Coastal Wetlands in the Lower Green Bay & Fox River AOC. International Association for Great Lakes Research, Brockport, New York. Oral Presentation. 12 June 2019.

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. The Global Freshwater Crisis: Lessons for the Amazon. Association of University Alumni Clubs. Iquitos, Peru. September 9, 2019.

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.

Makish, C.S., K.E. Kovalenko, J.P. Gathman, and J.J.H. Ciborowski. 2013. invasive phragmites effects on coastal wetland fish communities of the Great Lakes basin. 66th Canadian Conference for Freshwater Fisheries Research, Windsor, ON, January 3-5, 2013. Poster 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.

Monks, A., S. Lishawa, D. Albert, B. Mudrzynski, D.A. Wilcox, and K. Wellons. 2019. Innovative management of European frogbit and invasive cattail. International Association for Great Lakes Research. Brockport, NY

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., N.P. Danz, D.A. Wilcox, D.A. Albert, D. Rokitnicki-Wojcik, and J. Gathman. 2016. Great Lakes wetland plant Index of Biotic Integrity (IBI) development: balancing broad applicability and accuracy. Society of Wetland Scientists, Corpus Christi, TX.

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.

O'Reilly, K.E., J.J. Student, B.S. Gerig, and G.A. Lamberti. 2019. Metalheads: What can sport fish otoliths reveal about heavy metal exposure over time? Annual Meeting of the Society for Freshwater Science, Salt Lake City, UT.

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.

St.Pierre, J.I., K.E. Kovalenko, A.K. Pollock, and J.J.H. Ciborowski.2013. Is macroinvertebrate richness and community composition determined by habitat complexity or variation in complexity? 66th Canadian Conference for Freshwater Fisheries Research, Windsor, ON, January 3-5, 2013. Poster 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.

Stirratt, H., M.J. Cooper. Landscape Conservation Design for the Great Lakes. International Union for the Conservation of Nature World Conservation Congress, September 6-10, 2016, Honolulu, Hawai'i.

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., and S.A. Mackenzie. Control of invasive *Phragmites* increases breeding marsh birds but not frogs. Long Point World Biosphere Research and Conservation Conference, Simcoe, Ontario, Canada. Oral Presentation. 8 November 2019.

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. 2018. Application of the Great Lakes Coastal Wetland Monitoring Program to restoration projects in Lake Ontario wetlands. Society of Wetland Scientists, Denver, CO.

Wilcox, D.A. 2018. Wetland restorations in the Braddock Bay Fish and Wildlife Management Area of Lake Ontario. Great Lakes Coastal Wetland Monitoring Program. Midland, MI. (INVITED)

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., B.M. Mudrzynski, D.G. Uzarski, V.J. Brady, M.J. Cooper, and T.N. Brown. 2016. Great Lakes coastal wetland monitoring program assesses wetland condition across the basin. Society of Wetland Scientists, Corpus Christi, TX.

Wilcox, D.A., B.M. Mudrzynski, D.G. Uzarski, V.J. Brady, and M.J. Cooper. 2017. A second phase of the Great Lakes Coastal Wetland Monitoring Program to assess wetland health across the basin. Society of Wetland Scientists, San Juan, PR.

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., D.G. Uzarski, V.J. Brady, and M.J. Cooper. 2019. Student training in wetland science through the Great Lakes Coastal Wetland Monitoring Program. Society of Wetland Scientists, Baltimore, MD.

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

Bansal, S., S. Lishawa, S. Newman, B. Tangen, D.A. Wilcox, D.A. Albert, M. Anteau, M. Chimney, R. Cressey, S. DeKeyser, K. Elgersma, S.A. Finkelstein, J. Freeland, R. Grosshans, P. Klug, D. Larkin, B. Lawrence, G. Linz, J. Marburger, G. Noe, C. Otto, N. Reo, J. Richards, C.J. Richardson, L. Rogers, A. Schrank, D. Svedarsky, S. Travis, N. Tuchman, A.G. van der Valk, and L Windham-Myers. 2019. Typha (cattail) invasion in North American wetlands: biology, regional problems, impacts, desired services, and management. Wetlands 39:645-684.

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

Ciborowski, J.J.H., J. Landry, L. Wang and J. Tomal. 2020. Compiling and Assessing Environmental Stress and Biological Condition Data for the Detroit River Area of Concern. Prepared for Environment and Climate Change Canada, Toronto, ON.

Ciborowski, J.J.H., P. Chow Fraser, M. Croft, L. Wang, J. Buckley, J.P. Gathman, L.B. Johnson, S. Parker, D. Uzarski and M. Cooper. 2015. Lake Huron coastal wetland status - Review, assessment and synopsis of the condition of coastal wetlands and associated habitats. Technical report prepared for The Lake Huron Binational Partnership.

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.

Des Jardin, K. 2015. Water chestnut: field observations, competition, and seed germination and viabllity in Lake Ontario coastal wetlands. M.S. Thesis. SUNY-The College at Brockport, Brockport, NY.

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

Dumke, J.D., G.M. Chorak, C.R. Ruetz III, R.A. Thum, and J.N. Wesolek. 2020. Identification of Black Bullhead (*Ameiurus melas*) and Brown Bullhead (*A. nebulosus*) from the Western Great Lakes: Recommendations for Small Individuals. *The American Midland Naturalist* 183: 90-104.

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

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

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

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

Heminway, A.W. 2016. Response of Typha x glauca to phosphorus, hydrology, and land use in Lake Ontario coastal wetlands. M.S. Thesis. SUNY-The College at Brockport, Brockport, NY.

Hohman, T. 2019. Bird community response to change in wetland extent and lake level in Great Lakes coastal wetlands. M.Sci. Thesis, University of Wisconsin, Green Bay, Wisconsin. 41 pp.

Hohman, T.R., R.W. Howe, D.C. Tozer, E.E.Gnass Giese, A.T. Wolf, G.J. Niemi, T.M. Gehring, G.P. Grabas, and C.J. Norment. 2020. Bird Community Response to Changes in Wetland Extent and Lake Level in Great Lakes Coastal Wetlands. In preparation for submission to Journal of Great Lakes Research

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

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Appendix

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

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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
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37. http://www.seattlepi.com/news/science/article/Snail-harmful-to-ducks-spreading-in-Great-Lakes-5959538.php
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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.