Implementing the Great Lakes Coastal Wetland Monitoring Program

Semiannual Progress Report

October 1, 2020 – March 31, 2021

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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 have finished sampling the wetlands again for the second time. During this second round (2016-2020), we have investigated sampling adjustments to ensure that water level fluctuations are taken into account and are assessing effects of these large water level changes on metrics and indicators. 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 sampling begin in June. Phenology is followed across the basin, so that the 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 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 current organization for the 2016-2021 period. Our project management team has not changed but there have been other changes. We have a new technical lead at GLNPO, Matt Pawlowski. Dr. Greg Grabas of Environment and Climate Change Canada has been promoted and daily management of the ECCC team is by Joe Fiorino, a long-time team member. The ECCC team collaborates with University of Windsor to sample sites on the Canadian side of Lake Ontario. Dr. Doug Wilcox has retired and was succeeded by Dr. Katherine Amatangelo, who worked alongside him for several years.

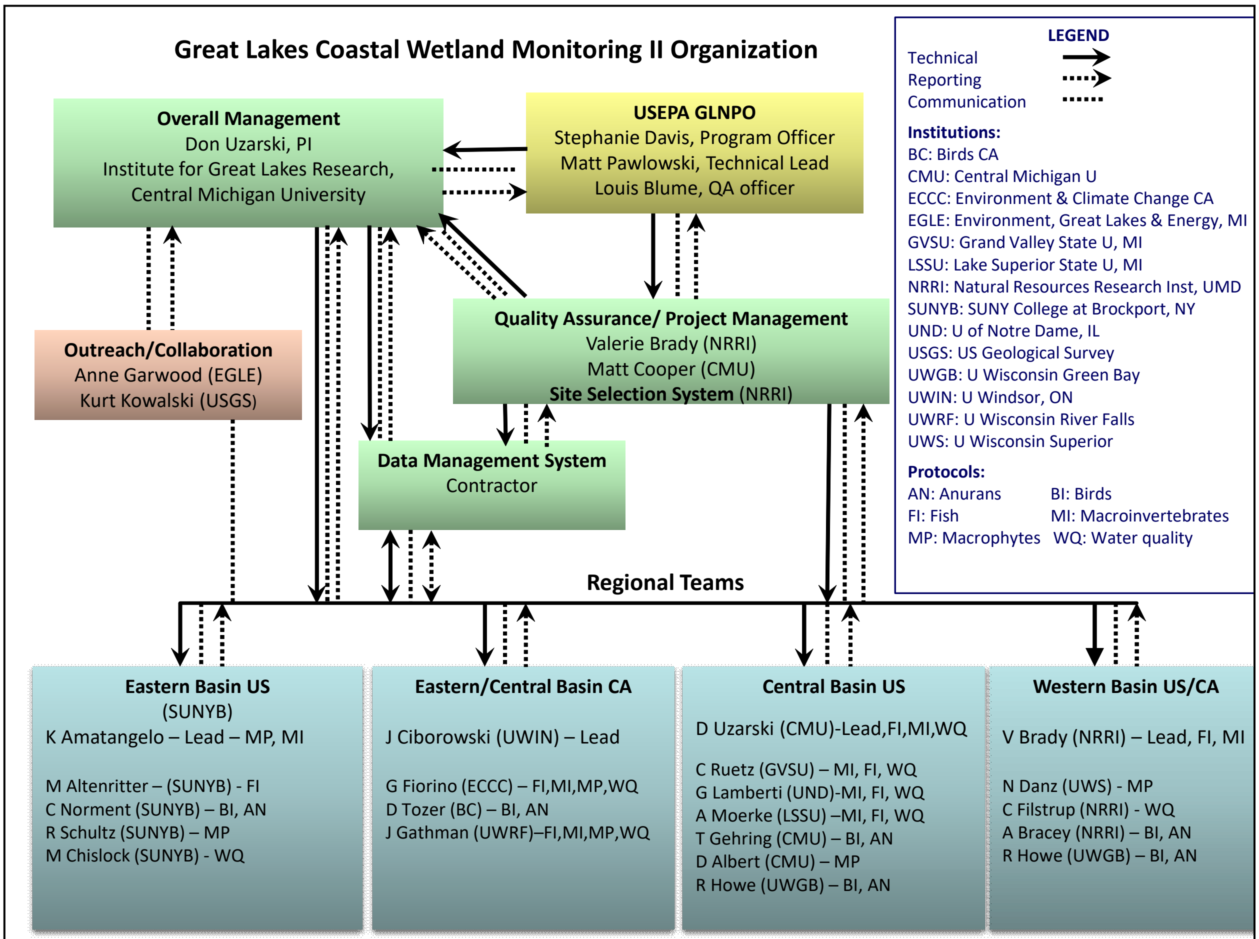

Figure 1. Current organizational chart for the program showing lines of technical direction, reporting, and communication separately.

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	2016				2017				2018				2019				2020				2021			
	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F
Funding received																								
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	X			
Data QC & upload to GLNPO					X	X			X	X			X	X			X	X		X	X	X		
Report to GLNPO		X		X		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 of Measure of Progress		Reporting Period (April 1, 2020 – September 30, 2020)		Project Status* (October 2016 – September 2020)	
		Number	**Percent**	**Number**	**Percent**
4.1.3	Number of Great Lakes coastal wetlands assessed for biotic condition	174	20%	978	100%
* (Not Started; Started; Paused; 25% Completed; 50% Completed; 75% Completed; 95% Completed; and 100% Completed)					

SITE SELECTION

Year ten site selection was completed in March 2021. Because we have now completed our 5-year sampling scheme twice (round 1: 2011-2015; round 2: 2016-2020), we are now beginning round 3 through our list of Great Lakes coastal wetlands. 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. The list of wetlands to be sampled this year (2021) was previously sampled in 2011 and 2016, with some differences as noted.

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, 2020, and 2021

Background
In 2011, a web-based database application was developed to facilitate site identification, stratified random selection, and field crew coordination. This database is housed at NRRI and backed up routinely. It is also password-protected. Using this database, potential wetland polygons were reviewed by PIs and those that were greater than four hectares, had herbaceous vegetation, had (or appeared to have) a lake connection navigable by fish, and were influenced by lake water levels 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, continued human activity and safe access for crews. 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 and to recover with rising water levels. Another component of this US/CA discrepancy is the lack of coastal wetlands along the Canadian shoreline of Lake Superior due to the rugged topography and geology. A final possibility is unequal loss of wetlands between the two countries, but this has not been investigated.

Strata

Geomorphic classes

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

Regions

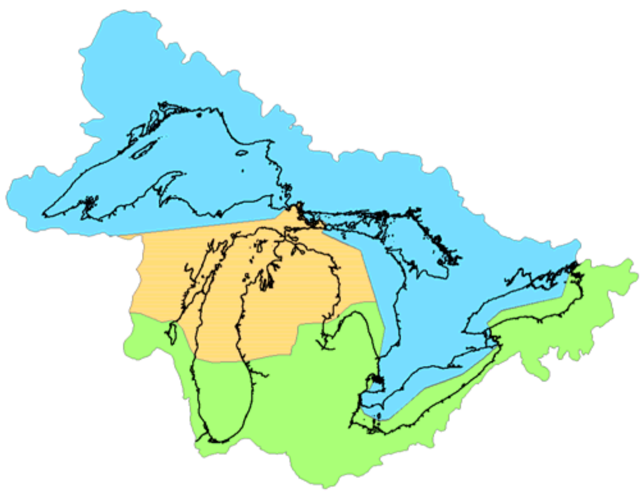

Figure 2. Divisions of lakes into regions. Note that stratification is by region *and* lake, so northern Lake Erie is not in the same region as Lake Superior, etc.

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).

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 2021, when panel *A* is being sampled for the third time, the 20 sites in sub-panel *b* of panel *E* 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. In 2020 we ran into the problem of being unable to sample sites because of the global pandemic, Covid-19. The site status code “could not sample” was added as a workflow state in the site selection list for crews to use to indicate this condition (Table 4). This occurred when crews could not safely get to sites due to pandemic restrictions; such sites tended to involve state or national border crossings, be located on islands, or be in areas experiencing pandemic outbreaks during the sampling window. This status was also used for high water levels preventing sampling.

Team assignment

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

Field maps

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. 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 informational tags, team assignments, and the history of comments made about the site, , including information from previous field crew visits intended to help future crews find boat launches and learn about any hazards a site poses.

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
could not sample	Added for 2020; indicates inability of crew to sample for some reason other than safety or lack of an appropriate wetland.	-1
visit reject	Visited in field, and rejected (no lake influence, etc.).	-1
will sample	Interim status indicating field visit confirmed sampleability, but sampling has not yet occurred.	1
sampled	Sampled, field work done.	1
entered	Data entered into database system.	2
checked	Data in database system QC-checked.	3

Browse map

The *browse map* feature allows the user to see sites in context with other sites, overlaid on either Google Maps or Bing Maps road or aerial imagery. Boat ramp locations are also shown when available. The *browse map* provides tools for measuring linear distance and area. When a site is 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.

2021 Site Selection

For 2021, 218 sites have been selected for sampling (Figure 3). Of these, 13 are benchmark sites. Another 18 sites are resample sites and 20 are pre-sample sites, which will be resample sites next year (2022). 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 this is our third sampling round, crews are familiar with most of the sites on the 2021 site list. However, site access issues are likely to again be exacerbated by high lake water levels and border closures due to the global pandemic (both the US-CA border and some tribal borders).

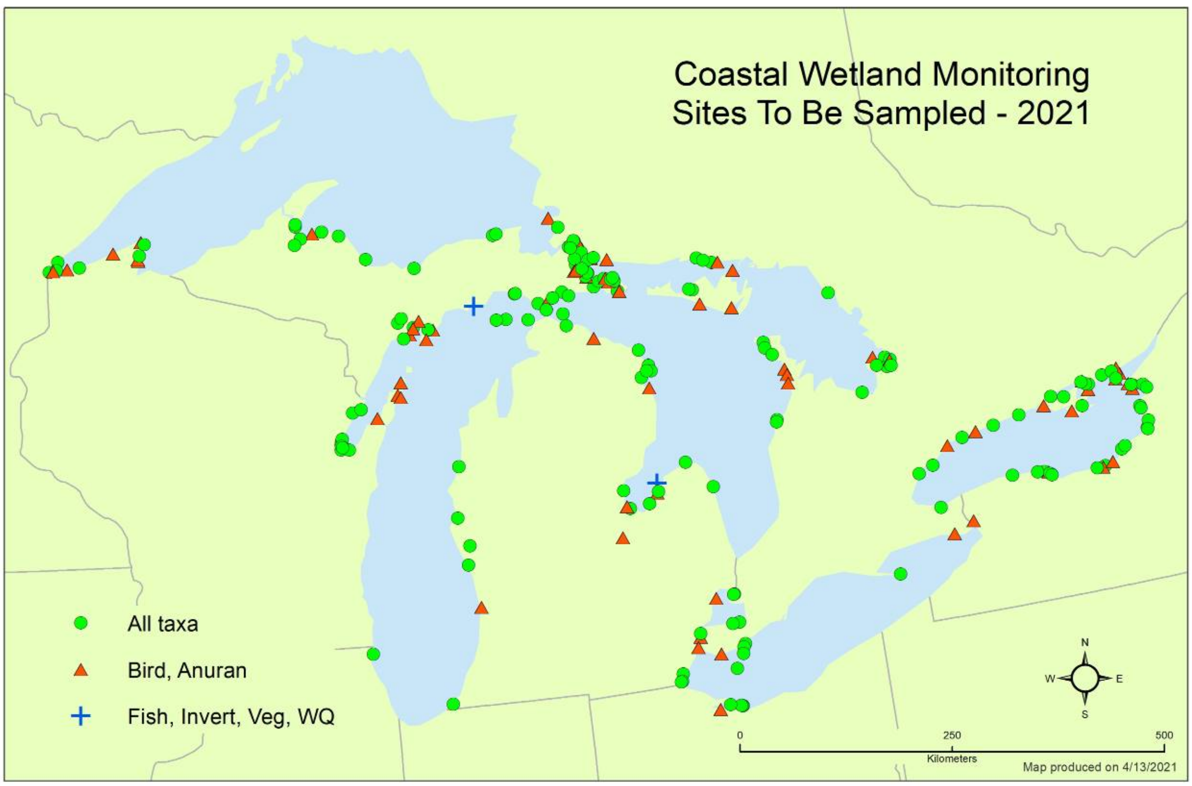

Figure 3. Locations of the 218 Great Lakes coastal wetlands to be sampled in 2021, color-coded by taxonomic groups. Sites assigned only to bird and anuran crews (due to their greater sampling capacity) are shown with a red triangle.

Benchmark sites are sites that are were not on the site list, are special interest sites that were too far down the site list and risked not being sampled by all crews, or are sites that are considered a reference of some type and are being sampled more frequently. Sites that were not on the site list typically are too small, disconnected from lake influence, or are not a wetland at this time, and thus do 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 get a number of requests to provide baseline data for restoration work.

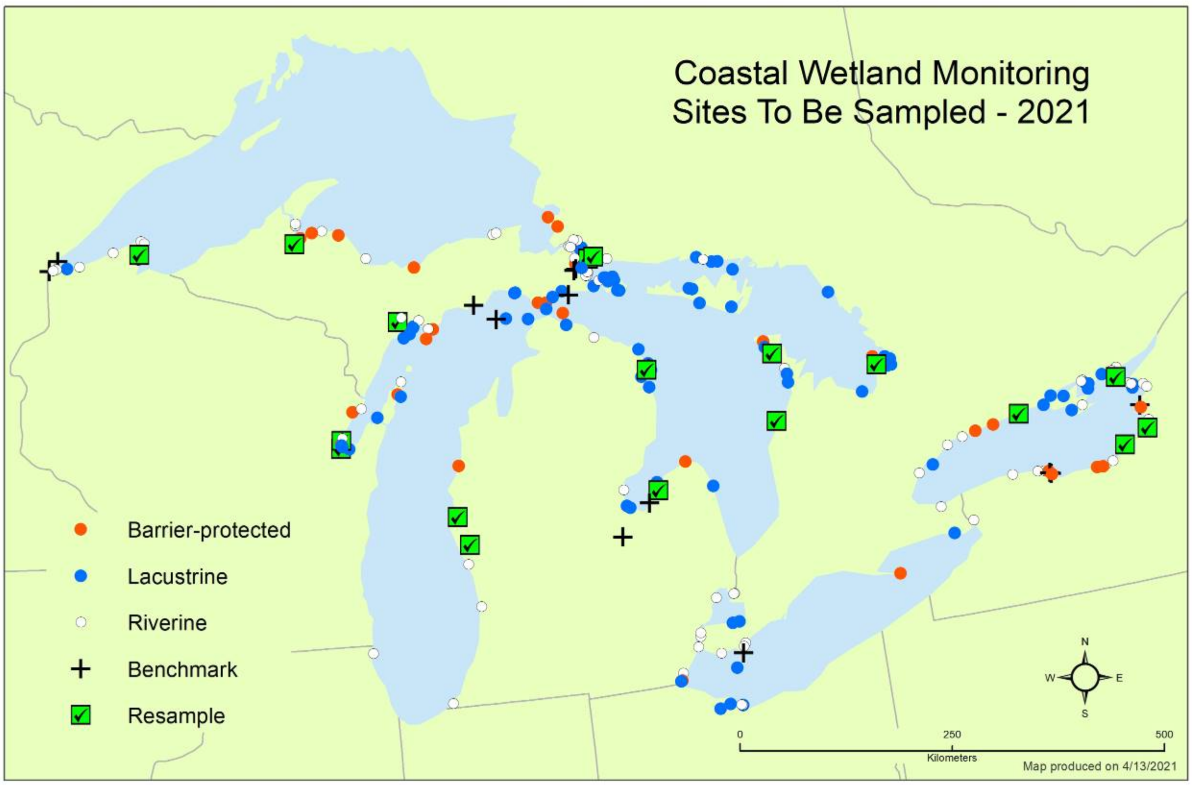

Figure 4. Locations of the 218 Great Lakes coastal wetlands to be sampled in 2021, color-coded by site type. See text for description of site types.

We now have approximately 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 and topographic differences along the Great Lakes coastline. Thus, each year several teams end up with fewer sites than they have 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 (2021). See individual team reports for how each team plans to train safely yet effectively during the on-going Covid-19 pandemic. In general, 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 points within each site, 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 can be 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 within sites, 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 and was done in both 2017 and 2018 as new staff joined the program.

Certification

To be certified in a given protocol, individuals must pass a practical exam. Certification exams 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 group, 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 and permissions for specific taxa group(s).

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

- Automated processes for individual users to request and confirm accounts;
- An account management page where a limited group of users with administrative privileges can approve and delete user accounts and change account settings as needed;
- Numerous validation rules employed to prevent incorrect or duplicate data entry on the various data entry/editing forms;

- Custom form elements to mirror field sheets (e.g. the vegetation transects data grid), which makes data entry more efficient and minimizes data entry errors;
- Domain-specific “helper” utilities, such as generation of fish length records based on fish count records;
- Dual-entry inconsistency highlighting for anuran and bird groups using dual-entry for quality assurance;
- Tools for adding new taxa records or editing existing taxa records for the various taxonomic groups; and
- GPS waypoint file (*.gpx) uploading utilities and waypoint processing to support matching of geographic (latitude/longitude) coordinates to sampling points.

The CWMP data management system also provides separate webpages that allow researchers to download “raw” data for the various taxonomic groups as well as execute and download custom queries that are useful for supporting dataset review and QA/QC evaluations as data entry proceeds during, and following, each field season. Users from state management agencies are able to access the separate download pages for raw data and custom queries. Such organizations include GLNPO and its subcontractors and EGLE. 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 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 (2011-2020, 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, 211 wetlands in 2019, and 174 wetlands in 2020 (fewer wetlands sampled due to the global pandemic).

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.

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 ha.

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%
2020	55	32%	8,603	23%
CA total Round 2	**331**	**34%**	**31,843**	**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%
2020	119	69%	29,325	77%
US total Round 2	**647**	**66%**	**132,470**	**82%**
Overall Totals Round 1	**1010**		**151,446**	
Overall Totals Round 2	**978**		**164,312**	

Teams were able to sample more sites in 2014 due to higher lake levels on Lakes Michigan and Huron, which allowed crews to access sites and areas that have been dry or inaccessible in previous years. By 2015 water depths in some coastal wetlands had become so deep that crews had difficulty finding areas shallow enough to set fish nets in zones typically sampled for fish (cattail, bulrush, SAV, floating leaf, etc.). In 2017 Lake Ontario levels reached highs not seen in many decades. Water levels were again near historic highs in 2019 and 2020 and crews continued to report sampling challenges due to the high water, with coastal wetlands flooded out and only beginning to migrate upslope into areas that remain covered by terrestrial vegetation (shrubs, trees, etc.) or being blocked in this upslope migration by human land use or shoreline hardening. This highlights the difficulty of precisely determining the number of sampleable Great Lakes coastal wetlands in any given year, and the challenges crews face with rising and falling water levels.

Because of the Covid-19 global pandemic and because of continued high water, about 40 more sites than usual could not be sampled during summer 2020. The pandemic created the unusual situation of some field crews not being allowed to cross state borders or travel to areas deemed to be a high risk for Covid-19 spread. Moreover, no field crews were allowed to cross the US-Canada border in summer 2020. In a more typical year, field crews routinely move back and forth across the US-Canada border to sample sites that are near to them. Despite site trades among US and Canadian teams, some sites could not be sampled this year because no team could get there due to logistics or safety. With vaccination rates happening at high levels across the US, we are hopeful that field crews will have fewer access issues in 2021 due to Covid-19, but as of the time of this report, the US-Canada border remains closed.

Biotic Communities and Conditions

We can now compile good statistics on Great Lakes coastal wetland biota because we have sampled nearly 100% of the medium and large coastal wetlands that have a surface water connection to the Great Lakes and are hydrologically influenced by lake levels.

Wetlands contained 24 to 29 bird species on average; some sampled benchmark sites had only a few bird species, but richness at high quality sites was as great as 64 bird species (Table 7). There are many fewer anuran (calling amphibian) species to be found in Great Lakes coastal wetlands (8 total), and 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 2016 through 2020 (all of Round 2 sampling), presented to allow comparison with Round 1 sampling summaries (2011-

2015).

Country	Site count	Mean	Max	Min	St. Dev.
Birds					
Can.	275	28.5	64	11	10.7
U.S.	574	24.3	58	6	9.8
Anurans					
Can.	212	4.8	8	1	1.7
U.S.	521	4.2	8	1	1.3

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 not far behind. These data include the benchmark sites, many of which are in need of or undergoing restoration, so the minimum number of species can be quite low.

Calling anuran species counts show less variability among lakes simply because fewer of these species occur in the Great Lakes. Wetlands averaged about four 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, only a single species was 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 2016 through 2020 (all of Round 2 sampling), presented to allow comparison with Round 1 sampling summaries (2011-2015).

	Birds				Anurans			
Lake	Sites	Mean	Max	Min	Sites	Mean	Max	Min
Erie	115	28.6	52	10	112	3.9	7	1
Huron	248	25.0	64	7	204	4.4	7	1
Michigan	158	26.3	58	6	148	4.1	7	1
Ontario	218	24.8	54	7	185	4.9	8	1
Superior	110	24.2	46	9	84	4.2	8	1

An average of 9 to 12 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 19 (CA) or 27 (US) fish species. The average number of non-native fish species per wetland was approximately one, though some wetlands had as many as 4 (US). An encouraging sign is that there are wetlands in which no non-native fish species were caught in fyke nets, although some non-native fish are adept at net avoidance (e.g., common carp).

Table 9. Total fish species in wetlands, and non-native species; summary statistics by country for sites sampled from 2016 through 2020 (all of Round 2 sampling), presented to allow comparison with Round 1 sampling summaries (2011-2015).

Country	Sites	Mean	Max	Min	St. Dev.
Overall					
Can.	161	9.5	19	3	3.7
U.S.	309	11.7	27	2	4.4
Non-natives					
Can.	161	0.7	3	0	0.8
U.S.	309	0.8	4	0	0.8

From 2016-2020, we collected no non-native fish in 44% of Great Lakes coastal wetlands sampled, and we caught only one non-native fish species in 40% of Great Lakes coastal 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.

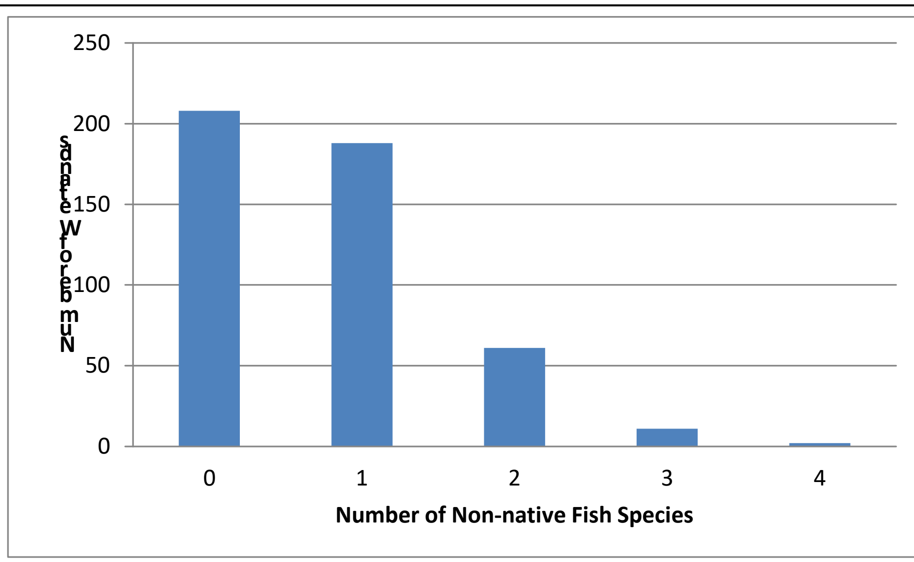

Figure 5. Number of Great Lakes coastal wetlands containing non-native fish species. Data from 2016 through 2020.

Total fish species did not differ greatly by lake, averaging 2-13 species per wetland (Table 10). Lake Michigan wetlands had the highest maximum number of species (27), with the other lakes all having similar maximums of 20-22 species. Because sites in need of restoration are included, some of these sites had very few fish species, as low as two. Wetlands in lakes Huron and Ontario averaged the lowest mean number of non-native fish species captured (about 0.6 non-native species per wetland) and Lake Erie wetlands had the highest, averaging 1.1 non-native fish species per wetland. 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 2016 through 2020 (all of Round 2 sampling), presented to allow comparison with Round 1 sampling summaries (2011-2015).

		Fish (Total)			Non-native		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	67	10.0	21	3	1.1	3	0
Huron	164	11.5	22	3	0.6	3	0
Michigan	77	11.7	27	4	0.8	4	0
Ontario	103	9.5	20	2	0.7	3	0
Superior	59	12.2	22	3	0.8	4	0

The average number of macroinvertebrate taxa (taxa richness) per site was about 37 (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 2016 through 2020 (all of Round 2 sampling), presented to allow comparison with Round 1 sampling summaries (2011-2015).

Country	Sites	Mean	Max	Min	St. Dev.
Overall					
Can.	183	37.2	61	18	9.9
U.S.	365	36.8	86	12	11.7
Non-natives					
Can.	183	0.6	4	0	0.8
U.S.	365	0.7	5	0	1.0

There is little variability among lakes in the mean number of macroinvertebrate taxa per wetland, with averages ranging from 33-40 taxa with lakes Ontario and Erie having lower averages than the upper lakes (Table 12). The maximum number of invertebrate taxa was highest in Lake Michigan wetlands (86) with the most invertebrate-rich wetlands in the other lakes having a maximum of 57-66 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 2016 through 2020 (all of Round 2 sampling), presented to allow comparison with Round 1 sampling summaries (2011-2015).

		Macroinvertebrates (Total)			Non-native		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	72	34.5	57	17	0.9	4	0
Huron	183	38.8	66	12	0.6	5	0
Michigan	99	39.9	86	14	0.8	3	0
Ontario	123	32.8	57	16	0.7	3	0
Superior	70	38.6	60	19	0.3	2	0

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

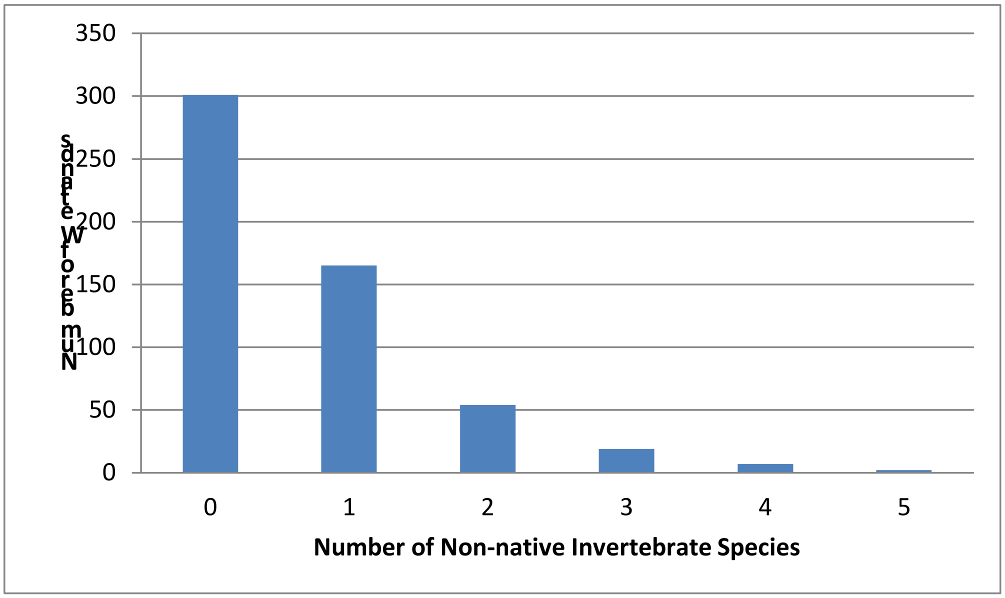

Figure 6. Number of Great Lakes coastal wetlands containing non-native invertebrate species. Data from 2016 through 2020.

We did not find any non-native aquatic macroinvertebrates in 55% of Great Lakes coastal wetlands sampled in the past 5 years (Figure 6), but in a handful of wetlands we found as many as 4-5 non-native invertebrate taxa.

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.

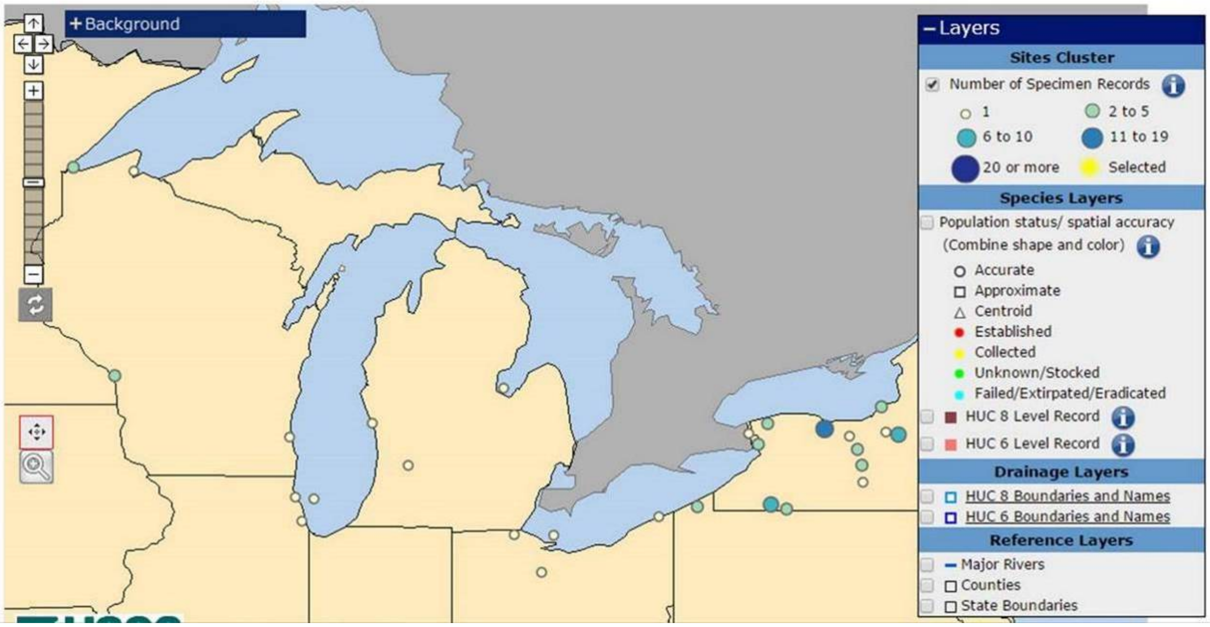

Figure 7. Locations of *Bithynia tentaculata* in USGS NAS website PRIOR to our project providing additional locations where they were collected.

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.

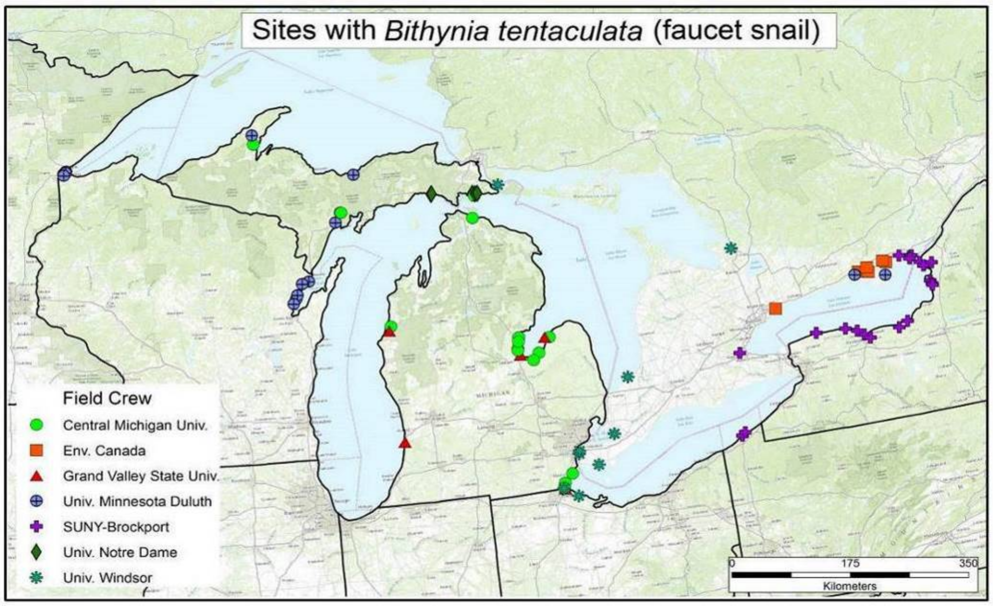

Figure 8. Locations of *Bithynia tentaculata* found by CWM crews, 2011 - 2013.

On average, there were approximately 35 macrophyte species per wetland (Table 13) with a maximum number of 70 species at exceptionally diverse sites. 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.

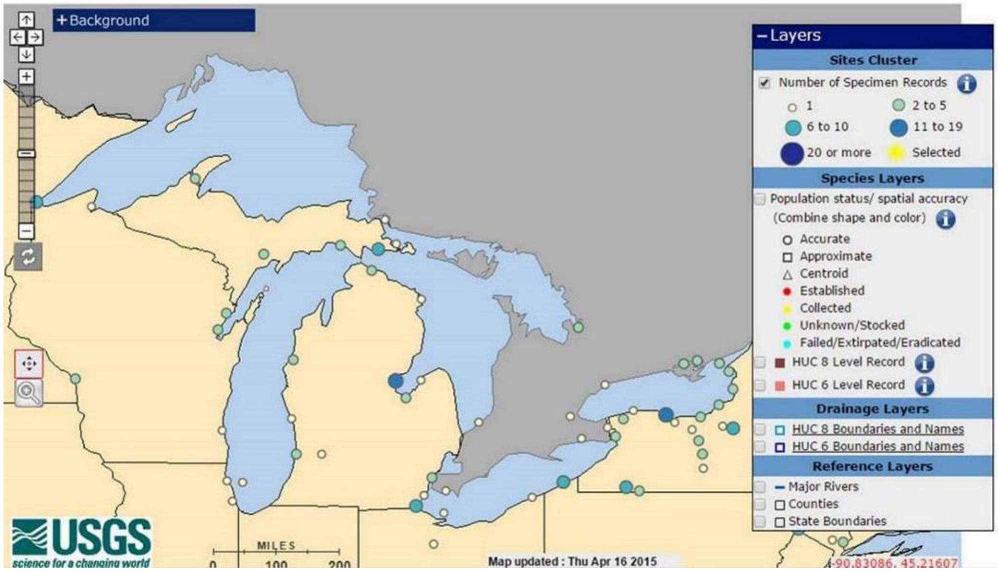

Figure 9. Locations of *Bithynia tentaculata* in USGS NAS website AFTER our project provided additional locations where they were collected; compare to Figure 6.

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 currently considered invasive. This update 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.

Coastal wetlands averaged 4-5 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 and non-native macrophytes in Great Lakes coastal wetlands; summary statistics by country. Data from 2016 through 2020 (all of Round 2 sampling), presented to allow comparison with Round 1 sampling summaries (2011-2015).

Country	Site count	Mean	Max	Min	St. Dev.
Overall					
Can.	188	34.0	71	6	14.6
U.S.	370	36.4	79	0	15.4
Non-native					
Can.	188	4.9	13	0	2.7
U.S.	370	4.2	21	0	2.9

Lake Erie wetlands had the lowest mean number of macrophyte species (21, Table 14), with the other lakes' wetlands having higher mean numbers of species (35-40, Tabble 14). Maximum species richness in Lake Erie wetlands was also 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 (Table 14). Lake Superior had the lowest maximum number of non-native macrophytes in a wetland (7) and Lake Huron had the highest maximum number with 21. There are wetlands on lakes Huron, Michigan, and Superior where we did not detect invasive plants.

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 2016 through 2020 (all of Round 2 sampling), presented to allow comparison with Round 1 sampling summaries (2011-2015).

		Macrophytes (Total)			Non-native		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	74	21.5	53	6	5.1	10	1
Huron	181	38.2	79	3	3.3	21	0
Michigan	93	40.0	76	6	4.6	11	0
Ontario	140	36.9	79	8	6.6	16	2
Superior	70	35.3	64	0	1.9	7	0

Our macrophyte data have reinforced our understanding of the numbers of coastal wetlands that contain non-native plant species (Figure 10). Only 7% of 556 sampled wetlands lacked non-native species, leaving 93% with at least one. Sites were most commonly invaded by up to 7 non-native plant species and 13% 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.

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.

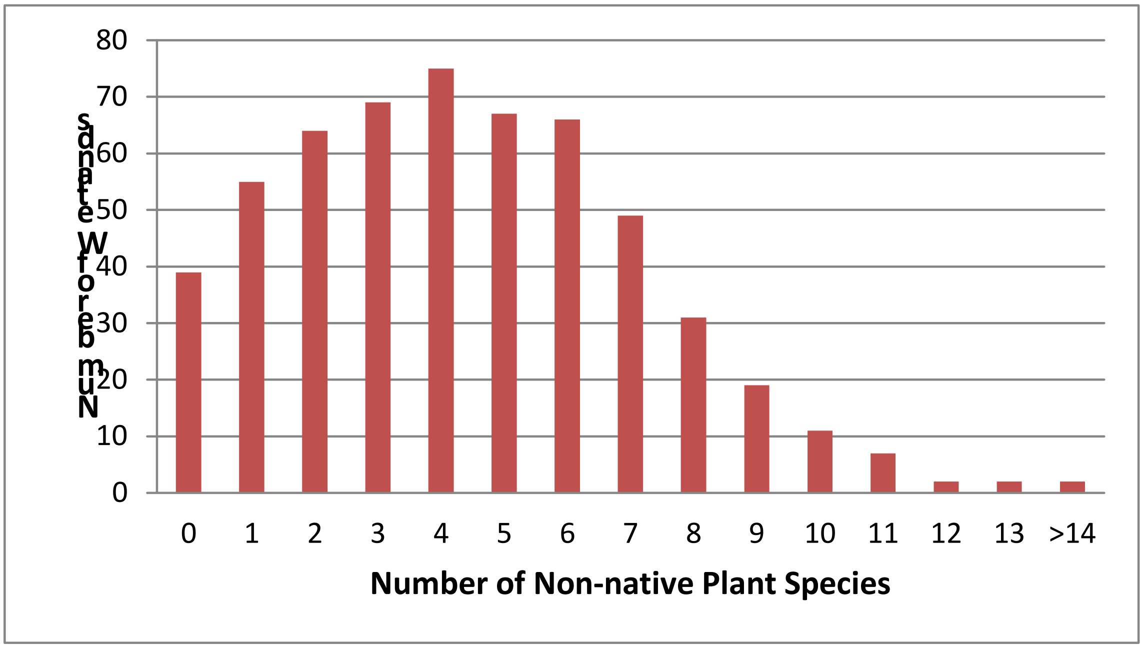

Figure 10. Number of Great Lakes coastal wetlands containing invasive plant species based on 2016 through 2020 data.

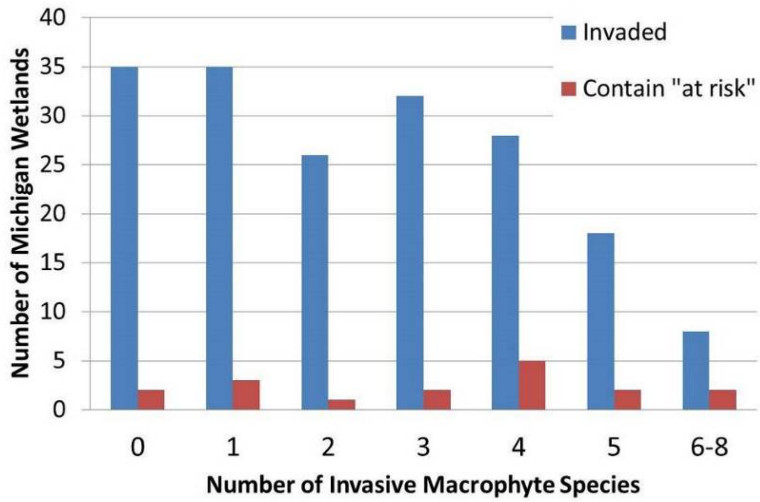

Figure 11. Number of state of Michigan Great Lakes coastal wetlands containing both invasive plant species and “at risk” plant species, based on 2011 through 2014 data.

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.

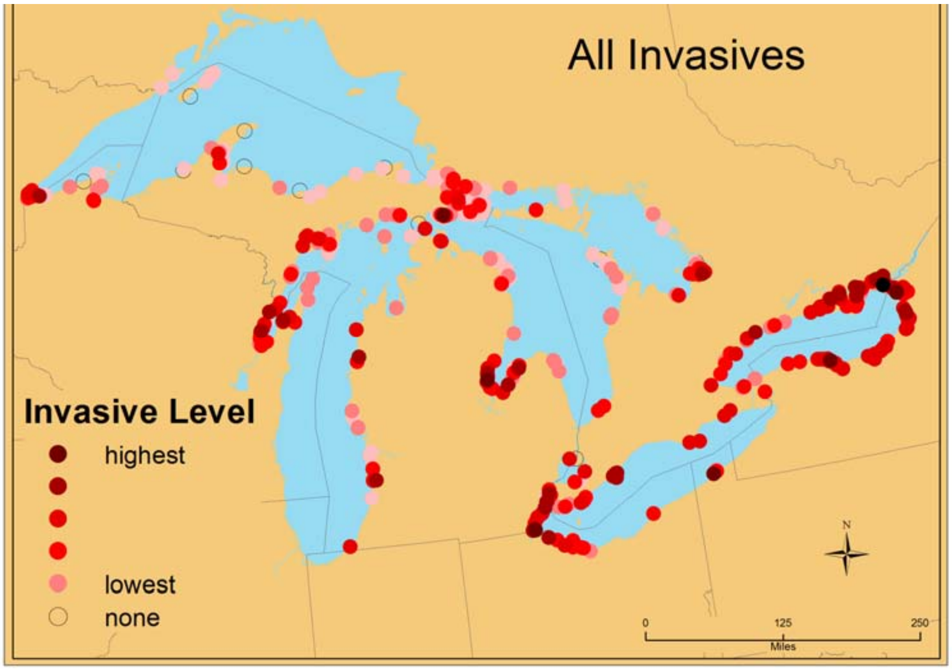

Figure 12. Level of "invadedness" of Great Lakes coastal wetlands for all non-native taxa combined across all taxonomic groups, based on data from 2011-2014.

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 anurans [calling amphibians]).

Macrophytic vegetation has been used for many years as an indicator of wetland condition (only large plants; algal species were not included). One very common and well-recognized indicator is the Floristic Quality Index (FQI); this evaluates the quality of a plant community using all of the plants at a site. Each species is given a Coefficient of 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

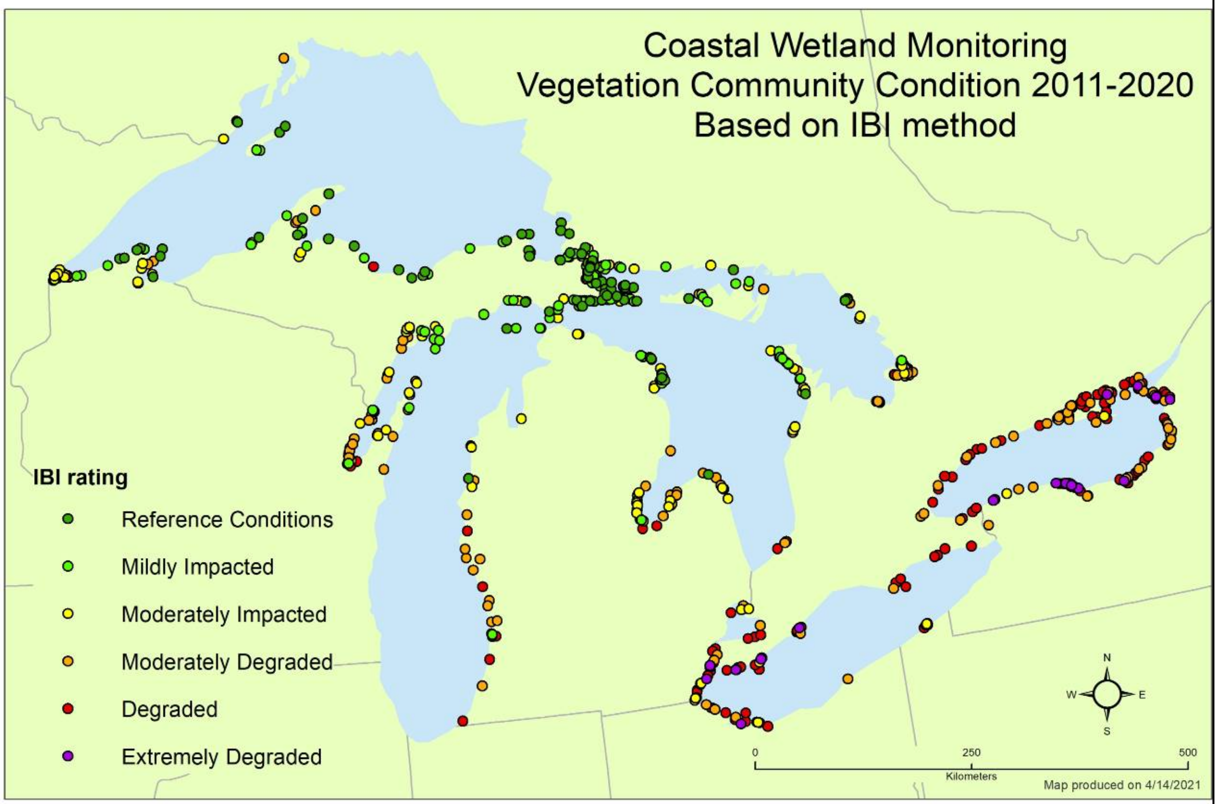

Figure 13. Condition of coastal wetland vegetation at sites across the Great Lakes. Circle color indicates vegetation community quality. The indicator is labeled "draft" while this indicator is investigated for robustness against varying water levels and latitude. Based primarily on data collected between 2016 and 2020, with 2011-2015 data used for sites only sampled in those years.

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 for 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, or other factors.

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 14). In 2019 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.

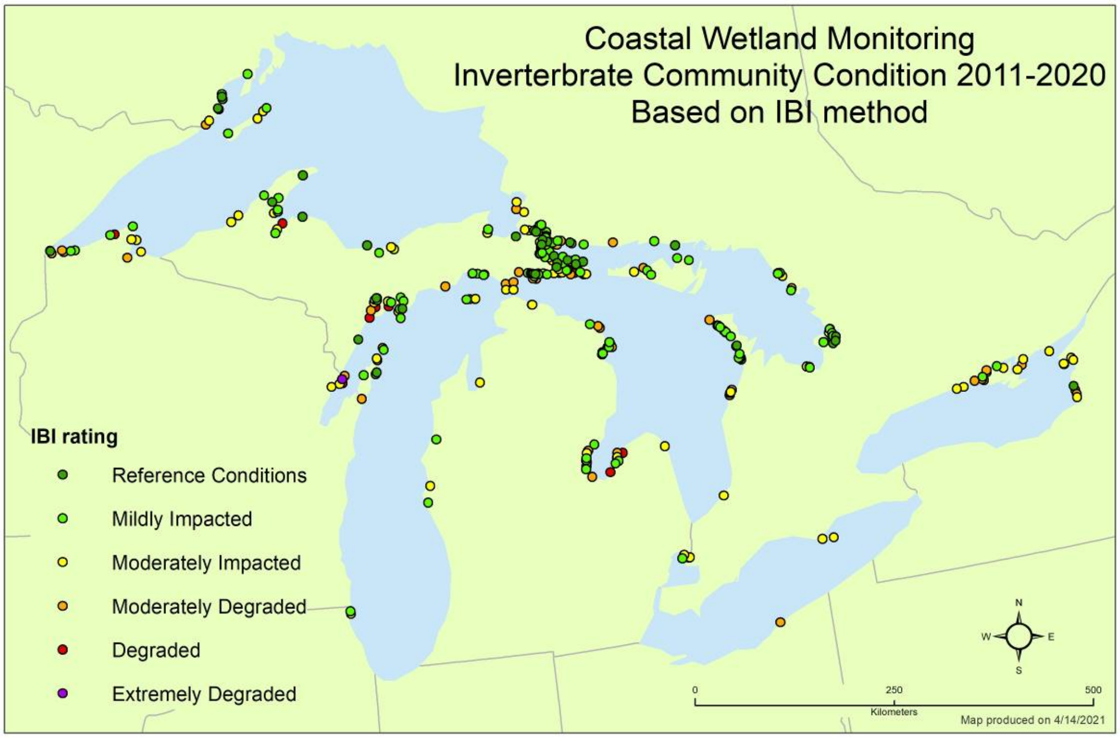

Figure 14. Condition of coastal wetland macroinvertebrate communties at sites with bulrush or wet meadow zones. Based primarily on data collected between 2016 through 2020 with data from 2011-2015 used for sites that were only sampled in those years.

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 types 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.

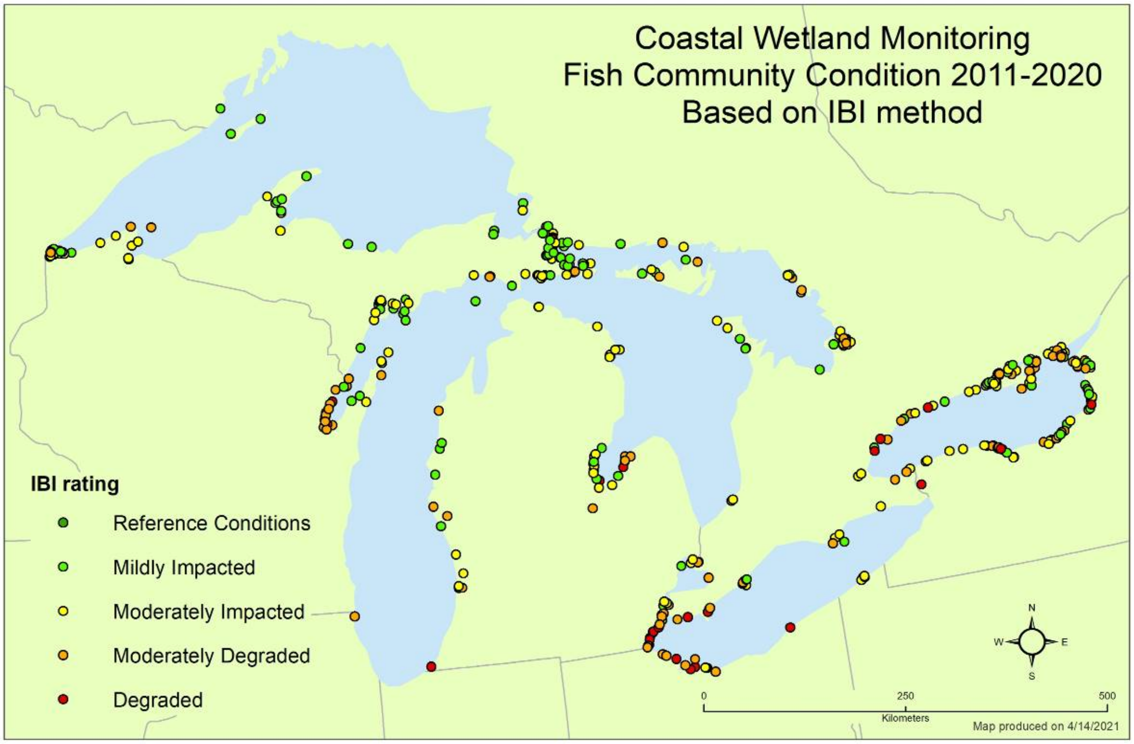

Figure 15. Condition of coastal wetland fish communties at sites with bulrush, cattail, lily, or submerged aquatic vegetation zones. Based primarily on data collected between 2016 through 2020 with 2011-2015 data used for sites that were only sampled in those years.

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 2021. 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.

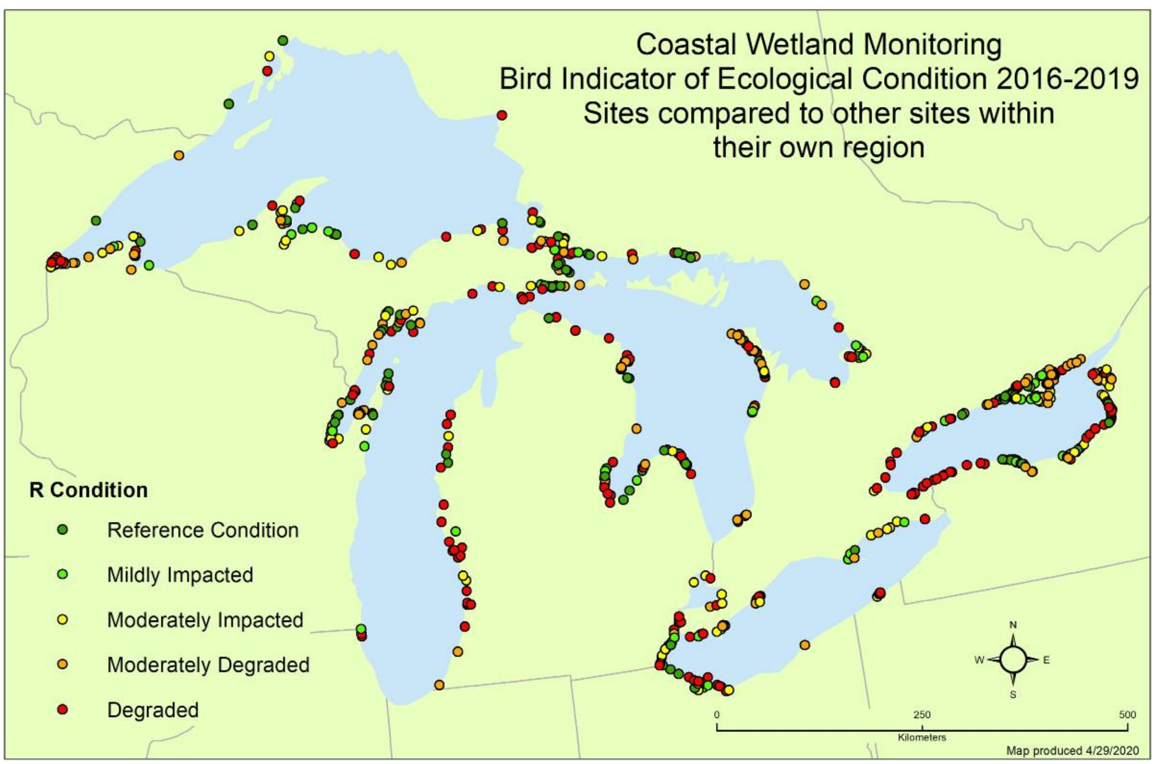

Figure 16. Condition of coastal wetland bird communties with wetlands compared regionally (see text for regions). This indicator is based on the IEC method using data collected primarily between 2016 and 2019.

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 ($p = 0.20$).

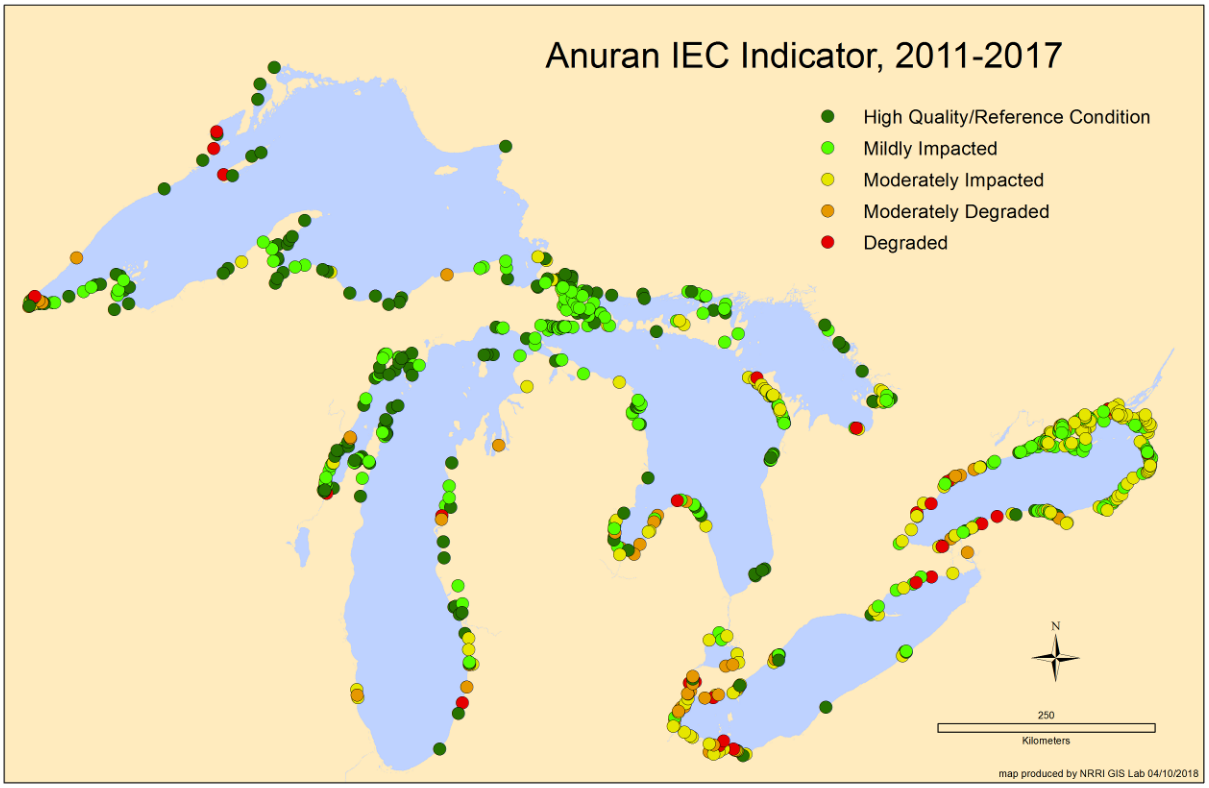

Figure 17. Condition of coastal wetland calling anuran communties. This indicator is based on the IEC method using data from 2011 through 2017.

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)

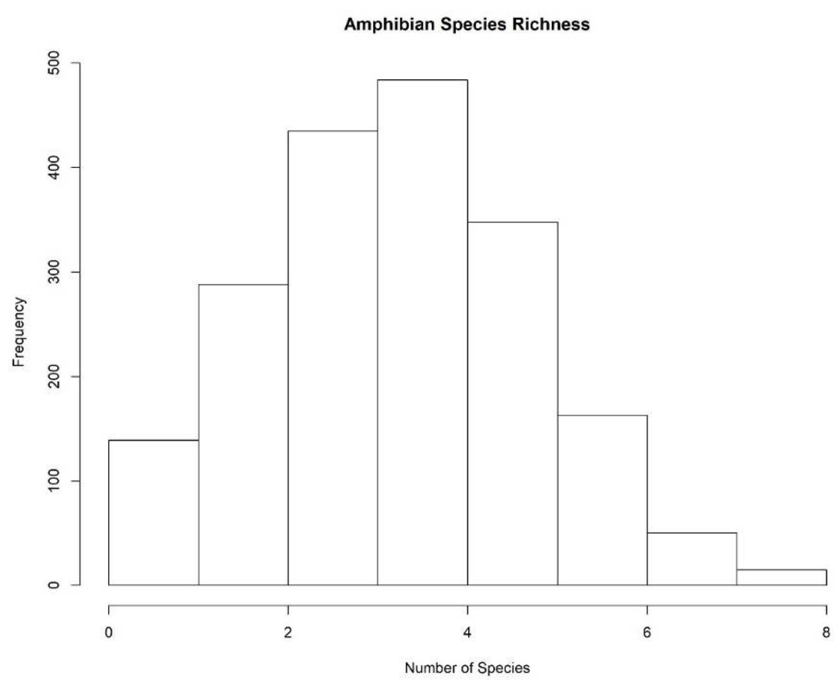

Figure 18. Distribution of anuran species richness at coastal wetland sample points from 2011-2017. Number of species refers to the total number of species recorded during three visits to the point during a given year.

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).

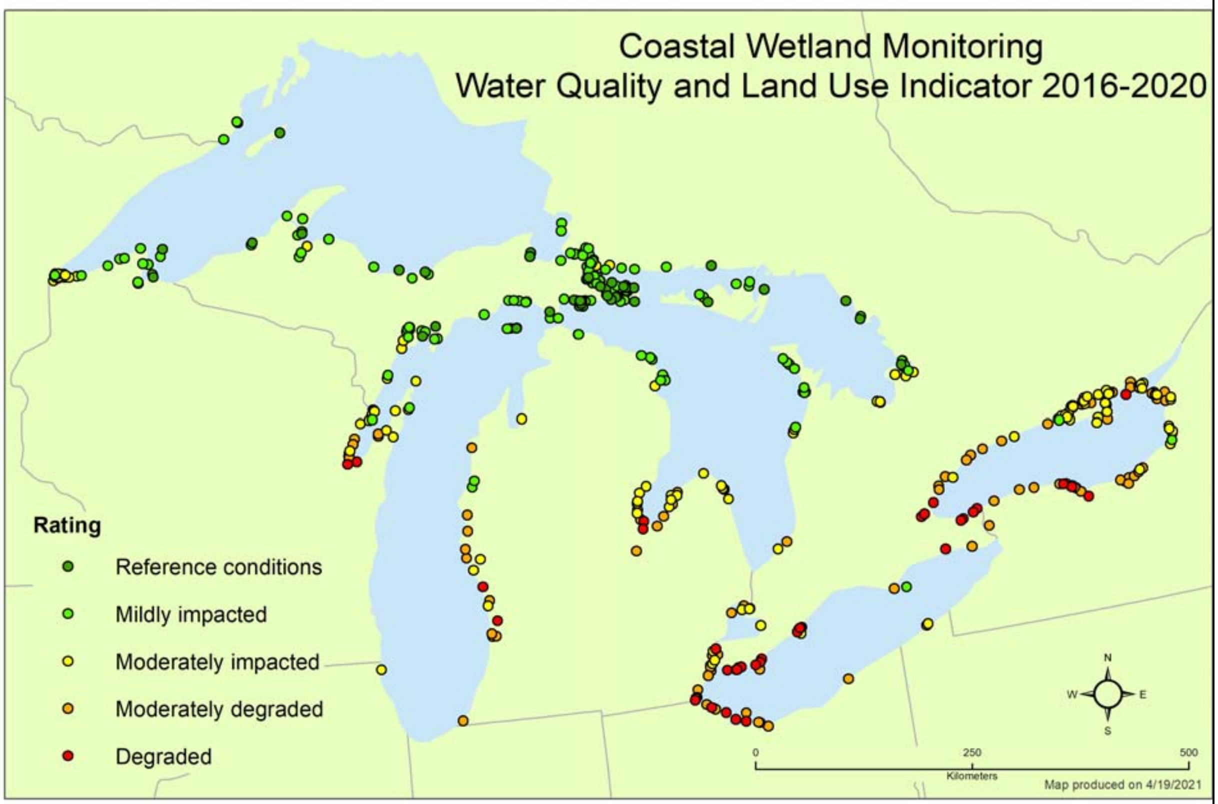

Figure 19. Disturbance gradient (SumRank) indicator. This indicator is based on landscape stressor data, site-based stressor data, and site water quality data. This is based on data collected from 2016 through 2020.

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 20). 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 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 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 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;
- **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. User requests for CWMP datasets are handled through a formal process which involves the requestor submitting a letter detailing the request and providing assurances regarding maintaining the publication rights of the CWMP team. Additional pages and tools available to "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).

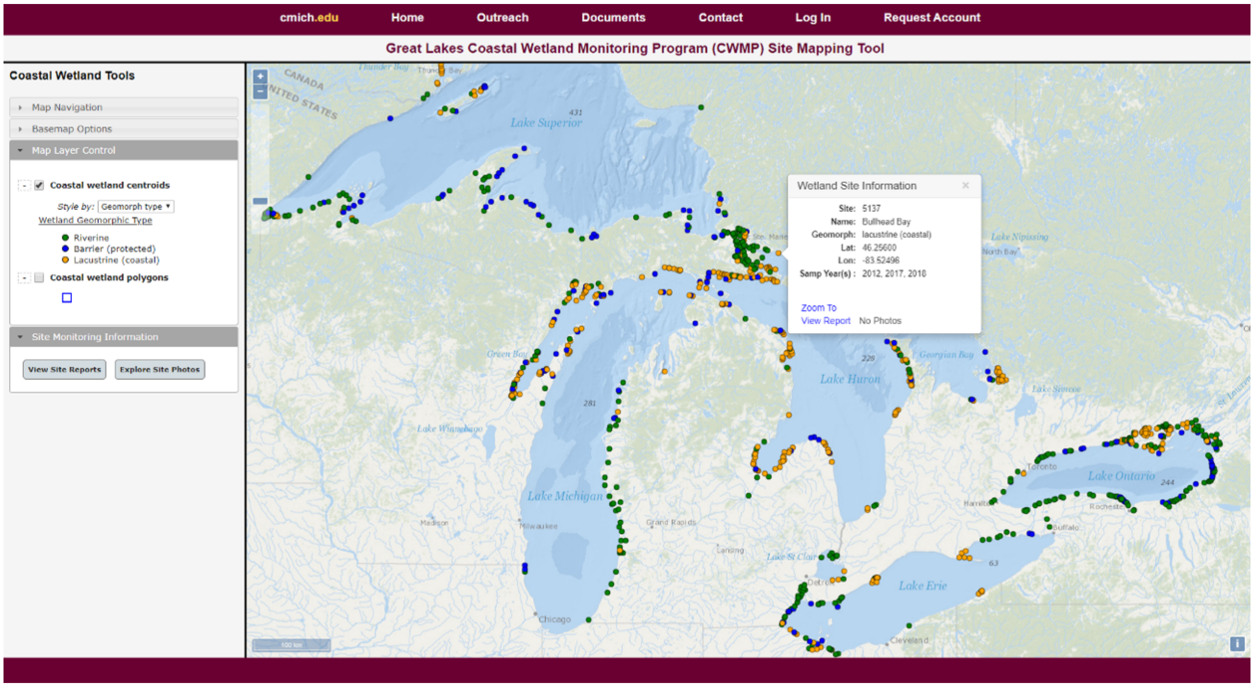

Figure 21. Coastal Wetland Mapping Tool – Public Version (geomorphic type view).

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 *Water Quality and Land Use Index*, which functions as a Disturbance Gradient and was previously called “SumRank.”

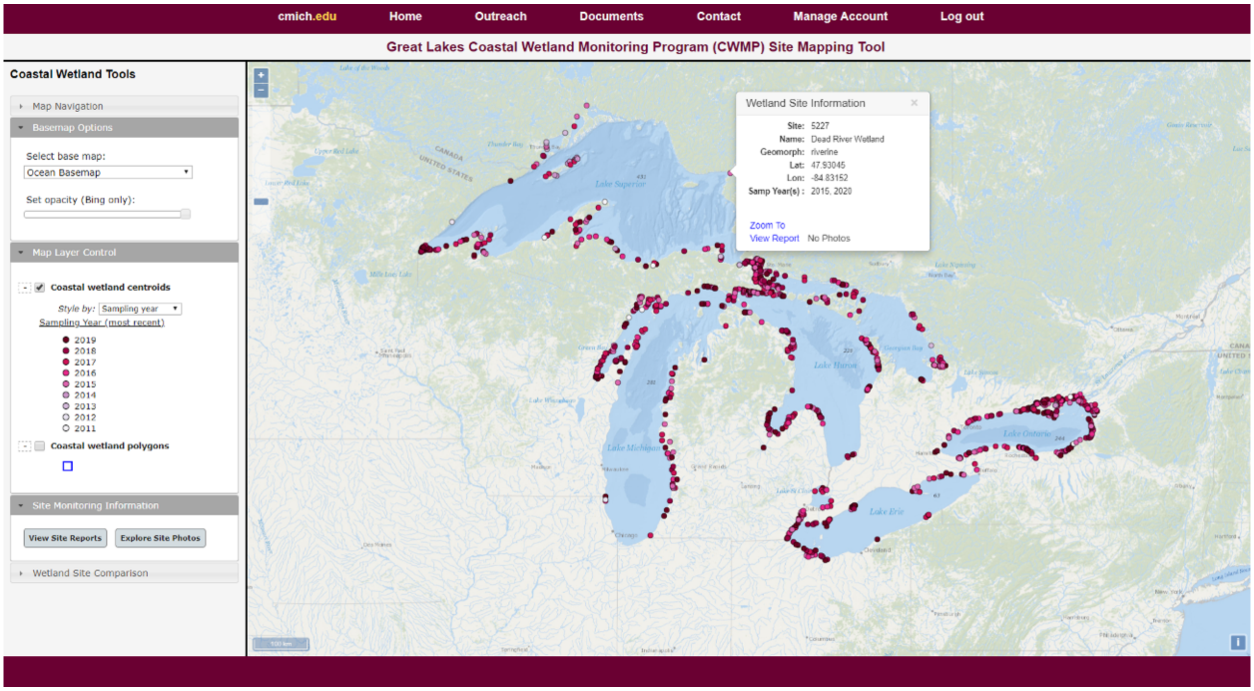

Figure 22. Coastal Wetland Mapping Tool – Public Version (sampling year view)

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.

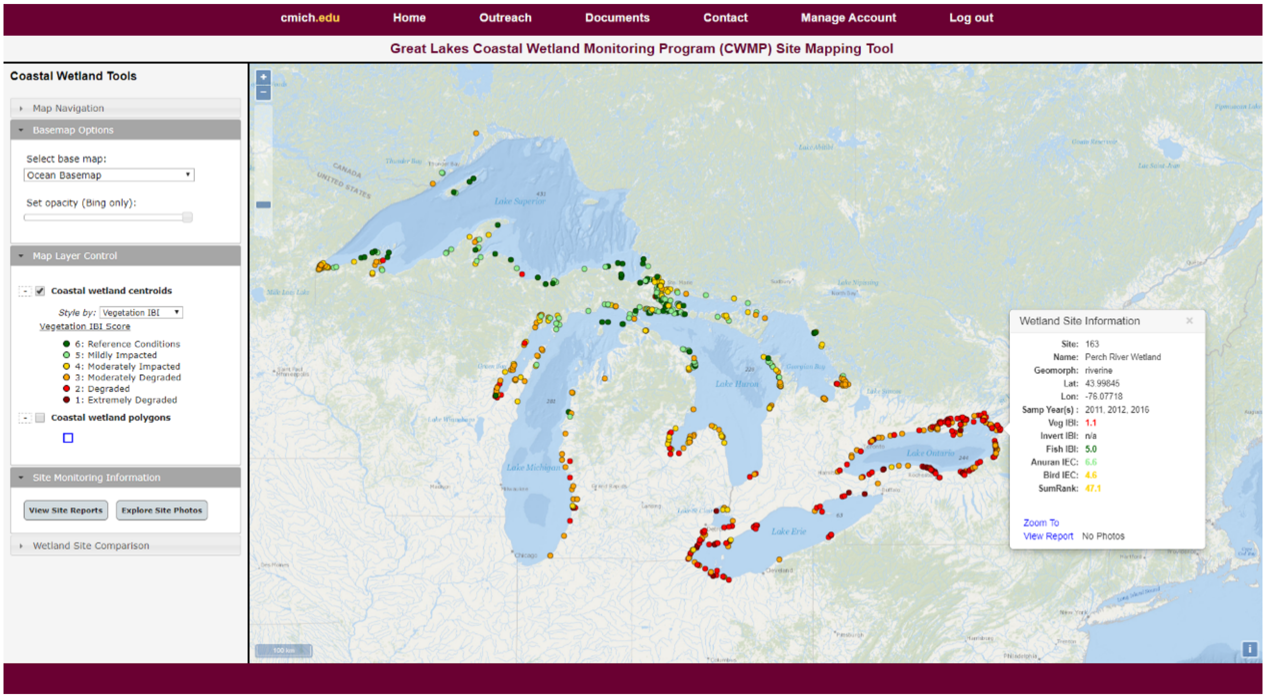

Figure 23. Coastal Wetland Mapping Tool with IBI scores displayed.

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/Water Quality and Land Use Index 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/ Water Quality and Land Use Index scores across the selected sites.

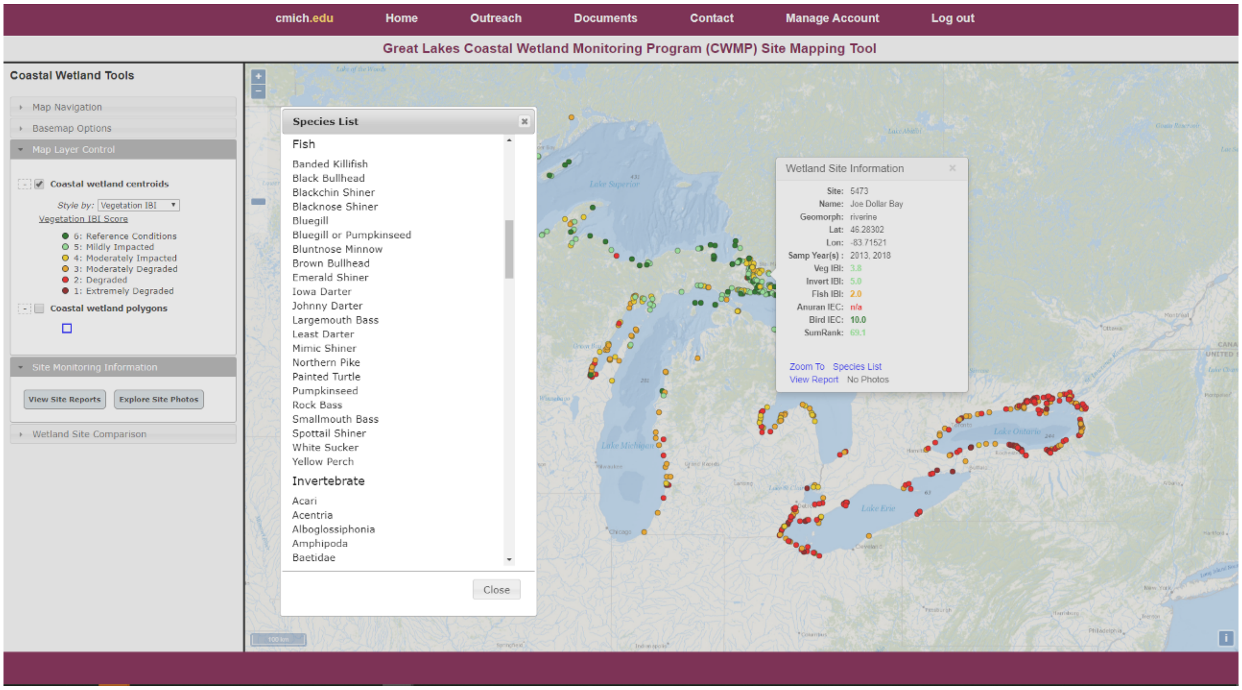

Figure 24. Coastal Wetland Mapping Tool with wetland macrophyte IBI scores and species list displayed.

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 Coastal Wetlands Decision Support Tool (link).

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.

A documentary was created about our monitoring program and the importance of Great Lakes Coastal Wetlands. This one-hour documentary aired on 275 PBS stations in 46 states, the Virgin Islands, and Washington D.C. beginning in July of 2020. It can be viewed at https://www.pbs.org/video/linking-land-and-lakes-hdo22u/

TEAM REPORTS

WESTERN REGIONAL TEAM: Valerie Brady (lead), Josh Dumke (Fish and Macroinvertebrates), Annie Bracey (Birds and Anurans), Nicholas Danz (Vegetation), and Chris Filstrup (Water Quality)

2020 Sample Processing, Data Entry, and QC

All 2020 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. Bird and anuran data QC is by double-entry comparison.

Results from 2020

Anurans:
In 2020, a total of seven species were recorded throughout our study sites, with 257 individuals and 53 full choruses counted (Table 16). The average number of individuals recorded per site visit was two. The average number of species detected per wetland was five, with a minimum

of three and a maximum of six. There were only two sites with six species recorded, site 1078: Nemadji River Wetland, a riverine wetland listed as a benchmark site, located in Superior, WI and site 1035: Chequamegon Wetland, a riverine wetland located on the Bad River Band of Lake Superior Chippewa tribal land near Ashland, WI.

Spring peepers were the most abundant species observed in all wetlands sampled, accounting for 38% of the anuran observations and the majority of full chorus observations (Table 17). Although there were very few wetlands sampled for anurans in 2020, the number of Wood Frog detections was low and there were no Chorus Frog detections at any of the wetlands, which was surprising.

Table 17. List of anurans recorded during 2020 surveys.

Species
American toad (*Anaxyrus americanus*)
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 02 June and 07 July. Surveys occurred once in the morning and once in the evening. A total of 69 identifiable species observations and 1,710 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, Yellow Warbler, Song Sparrow, Canada Goose, and Common Yellowthroat.

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 2020 (Table 18). Birds of special concern were observed in 10 of the 27 wetland sites surveyed in 2020. The most noteworthy observations included secretive marsh birds such as American Bittern, Virginia Rail, Pied-billed Grebe, and Sora Rail. American Bittern were observed in four wetlands. Virginia Rails were observed at two wetlands. Pied-billed Grebe and Sora rails were observed at one wetland site each. Although there were fewer sites sampled in 2020 due to travel restrictions, there were relatively low numbers of observations for both Virginia and Sora rails relative to previous years. Fourteen Bald eagles were observed at 8 sites. Common Loon were observed in 3 wetlands; four Sandhill Crane were observed at the Bibon Lake-Flag River Wetland in Port Wing, WI; and Belted Kingfisher were observed in seven wetlands surveyed in 2020.

As in 2016 – 2019, the bird and anuran teams included additional vegetation sampling at each of the point count locations in 2020. 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 2020 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*)

Per the request of the Wisconsin Department of Natural Resources and Great Lakes Audubon, we conducted additional bird surveys in the Allouez Bay Wetland (Site 1077), which required use of a boat to access the interior of the wetland. This wetland has been identified by both organizations as an important site for restoration with a focus on marsh bird habitat. The inclusion of these additional bird survey points, as well as the compilation of data that has been collected over the years at this benchmark site by all CWMP taxonomic teams will be used to guide restoration efforts. More specific restoration plans are currently being developed and will be implemented in the coming years.

Dr. Robert Howe of the University of Wisconsin, Green Bay, with input from the other Bird and Anuran co-investigators, continues to lead efforts to pursue 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 2021 CWM annual meeting, Dr. Howe discussed how the environmental gradient has been updated with data that includes a combination of habitat, landscape, geographic, and climate variables for

840 coastal wetland data points throughout the Great Lakes. Dr. Howe also discussed some additional modifications that have been made to the analysis over the past year and he anticipates completing a manuscript that describes these methods and their results as they pertain to the CWMP 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-2021 field season (September 2021) to discuss next steps and to identify a target journal for submission.

Fish and macroinvertebrates:
Of the 21 sites, 9 were on Lake Superior and 12 were on Lake Michigan. Six sites were designated as benchmark sites, one was a temporal re-sample site and five were pre-sample sites for 2020 and for future restoration work. Two sites could not be visited because they were across the United States border in Canada, and that border was closed to non-Canadian citizens due to Covid-19. A site on tribal land was inaccessible during the summer of 2020 because the Red Cliff Band closed access to non-members due to rising cases of Covid-19 in the area. We also had to take steps to protect our own employees when traveling afield to sample distant wetlands. We did not visit three wetlands because sampling those sites would have subjected the field team to prolonged stays in areas where Covid-19 cases were rapidly rising at the time.

Water levels were still high in Lake Michigan. Along the shoreline of site 1701 (Peshtigo Point Wetland) the NRRI field team observed several properties hardening their length of lakeshore with fill and large riprap (Figure 25). Field crews often noted that vegetation morphotypes were too deep to sample for fish, but they could sample water and invertebrates by leaning over the side of the work boat and submerging most of the D-frame dip net handle. Overall, 44 vegetation morphotypes were sampled for water quality and invertebrates.

Figure 25. Several residences were adding new riprap in 2020 to protect their properties from Lake Michigan waves. Lake Michigan water levels have been increasing for several years.

The NRRI team re-sampled two wetlands (7067 and 7068) in the harbor area of Marinette, Wisconsin. Both wetlands were restored by and sampled at the request of local Department of Natural Resource managers. In 2015 the NRRI field team sampled each of these wetlands before major restoration activities occurred. One of the intended restoration goals was to improve Lake Michigan fish access to, and use of, these wetlands. During our 2015 visit some shoreline work had started and silt fences were in place along much of the shoreline, but other restoration activities had not yet occurred. In 2020 the NRRI field team observed that a new boat access and navigation channel had been created within site 7067, and several boats were fishing within the site along a mat of submerged aquatic vegetation. That mat of vegetation contained the non-native invasive Eurasian watermilfoil, but was dominated by species of potamogeton and appeared to be a good place locals to catch Yellow Perch. At the neighboring 7068 site we observed several shoreline improvement activities such as wood duck nest boxes and tree plantings, but the high water of Lake Michigan for the last several years had flooded most, but not all, of the land where plantings had been placed (Figure 26). On a positive note, the expansive stands of invasive *Phragmites* observed at 7068 in 2015 were reduced to small patches that were not large enough to sample.

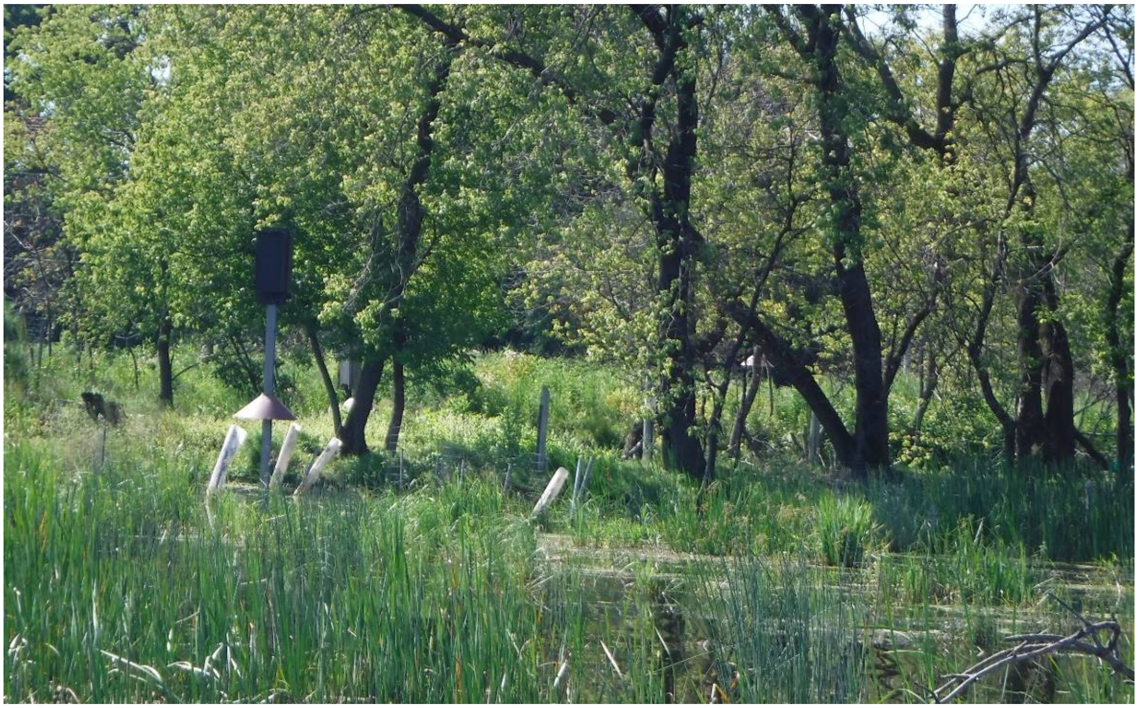

Figure 26. Restoration activities evident at site 7068, including wood duck boxes, sapling trees protected in tree tubes, and other vegetation protected from browsing animals by fencing.

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

Aquatic macrophytes:
In 2020, our vegetation surveys were undertaken on 23 sites in Lake Superior and Lake Michigan. Field data have been completely entered into the project database and QA/QC procedures are complete.

Jeremy Hartsock has joined the University of Wisconsin Superior team. Jeremy recently graduated with his PhD in plant biology. He will assist coordinating fieldwork logistics and analyzing the copious amounts of data obtained over past years of wetland monitoring.

Recently, we have taken interest in closely examining the Allouez Bay marsh located on the east side of Superior, Wisconsin (CWMP site 1077). Allouez Bay has been sampled more regularly than any other CWM wetland site along Lake Superior; six times over years 2011 - 2020. The site therefore serves as an ideal case study to evaluate plant responses along a continuum of increasing Lake Superior water levels (Fig 27).

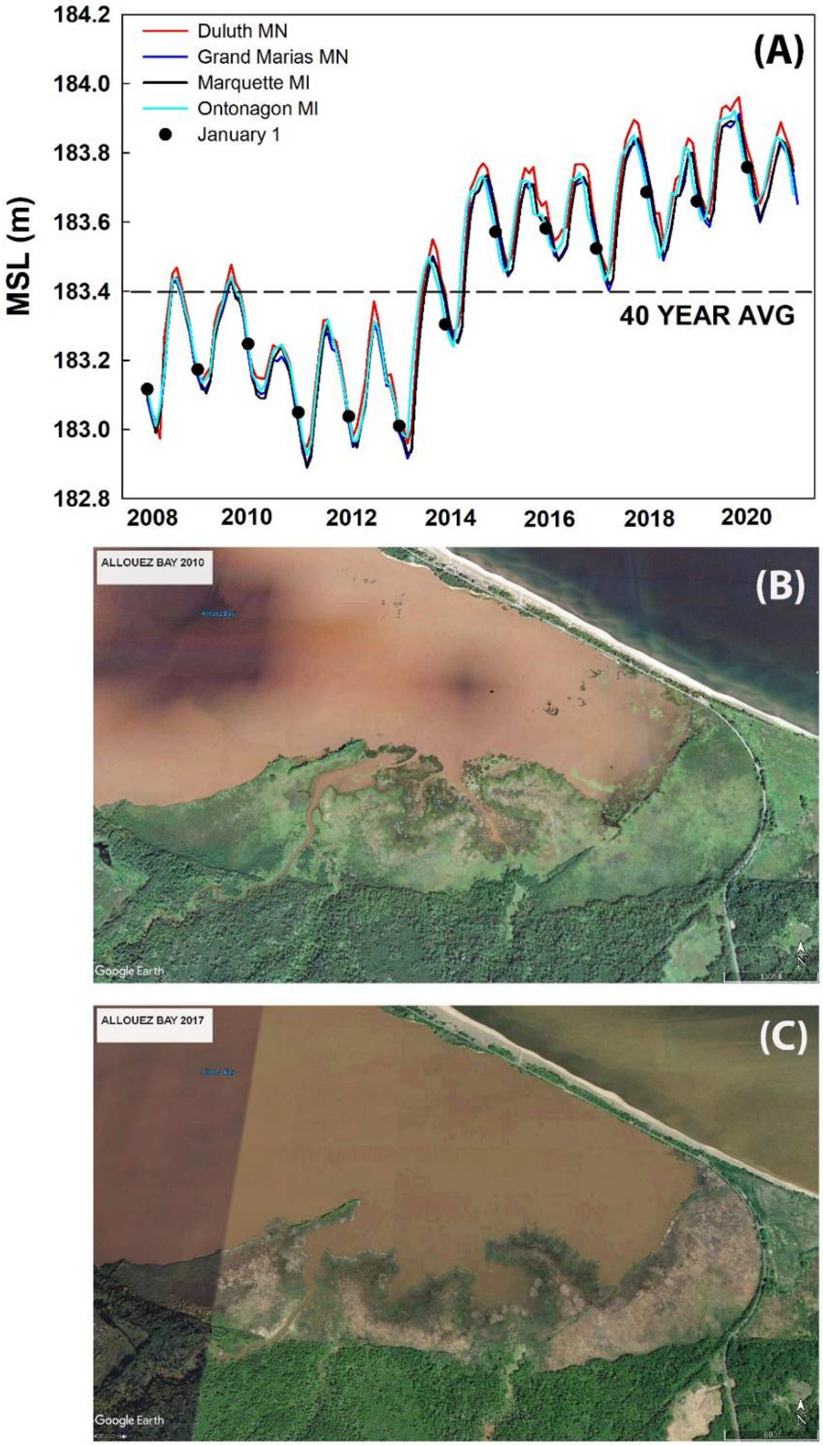

Figure 27. (A) Daily average Lake Superior water levels (2008 - 2020). The horizontal dashed line shows the long-term average water level (1980 - 2020). Source: National Oceanic and Atmospheric Administration (https://tidesandcurrents.noaa.gov/). (B) Allouez Bay wetland aerial photo, from August 2010. (C) Allouez Bay wetland aerial photo, from August 2017.

We used diversity indices, canopy cover estimates, coefficient of conservatism values, and multivariate community analysis to determine whether plant species richness, vegetation structure, floristic quality, and species composition tracked recent rising water levels. Over the six sampling campaigns we encountered 92 vascular plant species in the Allouez Bay marsh, five of which were non-native (*Iris pseudacorus*, *Lythrum salicaria*, *Phragmites australis*, *Typha angustifolia*, *Typha glauca*, and *Valeriana officinalis*). Compared to a previous report documenting vegetation patterns across the site, Koch (1981) encountered 120 vascular plant species, and dominant species were nearly identical to our observations 40 years later. While results are quite comparable between studies, Koch (1981) reported no encounters with non-native species (except for *Typha* sp.). At a whole site level, temporal plant species richness changes were non-significant ($p>0.05$). Furthest inland in the wet meadow zone, total plant cover has gradually decreased in later years (Fig 28).

Of note, in 2020 a submergent zone was not apparent at the site. Thus, submergent vegetation zones at Allouez Bay have been most impacted by record-high water levels. Despite clear wetland area reductions due to rising water levels, temporal changes in floristic quality across the entire marsh was not detected, with interannual mean C-values ranging from 4.9 to 5.7 (Fig 28). PERMANOVA analysis, however, revealed significant effects of year on plant community composition ($p<0.05$). Temporal composition changes were most apparent in the submergent zone. Relevant to previous Allouez Bay restoration efforts, the reintroduced native grass *Zizania palustris* generally increased in abundance from 2011 to 2017 but was not encountered in 2020.

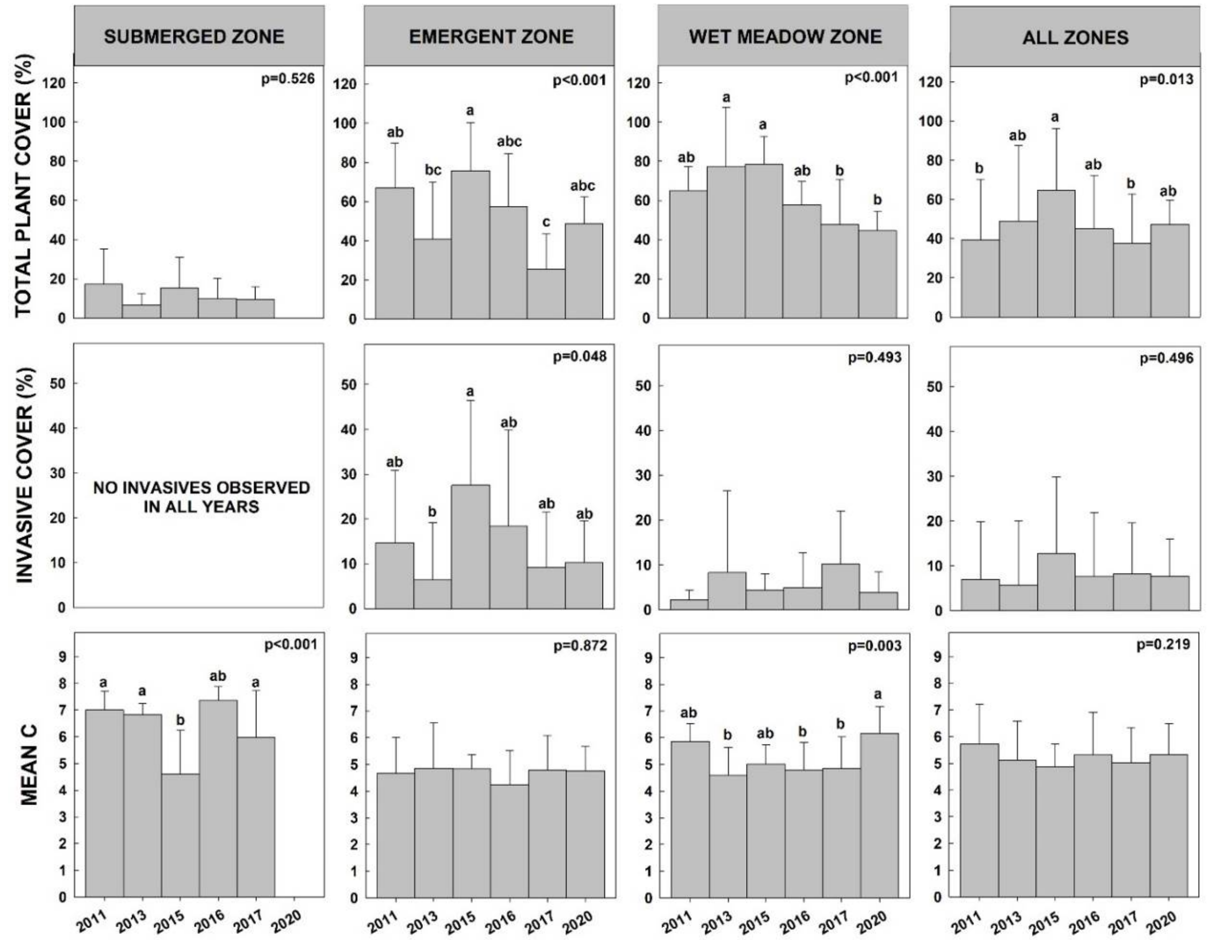

Figure 28. Mean total plant cover (%), mean invasive plant cover (%) and frequency weighted mean coefficient of conservatism values among submergent, emergent, wet meadow, and all zones combined at Allouez Bay. Error bars are standard deviation. Different letters indicate significantly different groups determined from a one-way ANOVA and Tukey's post hoc test, α = 0.05.

Other Activities

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 was accepted in the journal 'Biological Conservation' and per the agreement all bird and anuran co-investigators on the CWM project have had the opportunity to contribute to the manuscript and be included as co-authors (https://doi.org/10.1016/j.biocon.2020.108708). We expect to maintain communications regarding any potential future use of the CWM data by National Audubon and will continue to provide guidance on appropriate uses in future projects and analyses.

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 for which 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 2021. We will be involved in post-restoration monitoring of this site as well.

Restoration of Allouez Bay, Superior, WI

In 2020, Great Lakes Audubon and the Wisconsin Department of Natural Resources put together a collaborative team to assess the restoration potential of Allouez Bay, an extensive lacustrine coastal wetland complex located in Superior, WI. This wetland has been listed as a benchmark site by CWMP since 2011 and has been sampled for birds and anurans in many of the years following. In addition to the bird and anuran data, fish and invertebrate, water quality, and vegetation data have also been collected by other CWMP teams that have sampled this wetland periodically since 2011. These data will provide critical baseline information about the quality of the site which will be used to guide restoration efforts by identifying quality from degraded habitats within the wetland site. These data will be compiled with current data being collected by WIDNR (e.g., drone aerial imagery and vegetation surveys) and Great Lakes Audubon (e.g., additional bird surveys conducted in the interior of the wetland) to model different restoration scenarios to identify which activities will be most effective in enhancing the quality of the wetland for birds and taxa. On-the-ground restoration activities are not scheduled to begin until 2022-2023.

Fish Investigations

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.

A spin-off pilot project began in 2019 to investigate how well fyke net fish catches agree with fish eDNA collected from nearby benthic sediment. Making this linkage will allow us to investigate fish use of vegetation types that cannot be fished, such as wild rice beds in which standard fish sampling is considered too destructive of the rice plants. Dr. Valerie Brady and Dr. Chanlan Chun at the Natural Resources Research Institute lead the eDNA pilot project.

Field Training

Birds and Anurans:

Due to work-related restrictions in travel associated with the COVID-19 pandemic, there will be no in-person field training for birds or anurans in 2021. Training for anuran surveys will be held virtually on 9 April 2021 and bird survey training will take place either in-person or virtually on 25 & 26 May 2021. 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 ongoing. Fortunately, all field personnel scheduled to conduct anuran and/or bird surveys in 2021 have surveyed for 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 insure that their hearing is within the normal range. Rules for site verification, safety issues including caution regarding insects (e.g., Lyme's disease), GPS and compass use, and record keeping are also included in field training to insure that the guidelines in the QAPP are being followed. All individuals involved in conducting the surveys in 2021 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 new and returning field observers will review the current QAPP and SOPs and any new observers will 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 anuran records will be completed (100%) by September 2021.

Fish, Macroinvertebrates, Water Quality and Aquatic Macrophytes:
Fish, macroinvertebrate and water quality sampling training will be held virtually in June due to continuing Covid-19 restrictions and will continue in person at the first field sites sampled in Green Bay. Nearly all crew members are returning crew with multiple (often many) years of experience, so only 1-2 new field crew will need to be trained. All field technicians will be trained in and tested on all standard procedures, including a fish identification exam. 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, 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 crew members. All aquatic macrophyte crew members except new postdoc Jeremy Hartsock are long-time crew and only need a refresher. Dr. Hartsock will receive training in June.

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 2021 a total of 26 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. Given continued travel restrictions to Canada, all of these 26 sites are in the U.S. Of these 26 sites, 11 are marked as potentially sites that will be excluded from sampling in 2021. One site is on private property (site 1076) and we have not been successful in contacting property owner in the past. Another site (site 1062) is located on Red Cliff Band of Lake Superior Chippewa land and we are currently seeking permission to access this site. In 2020, we were not granted permission to access sites on Red Cliff lands due to access restrictions associated with Covid-19 and we assume that similar restrictions will still be in place for this field season. The remaining 9 wetlands will require a site visit to determine whether or not the wetland meets sampling criteria (e.g., not appropriate emergent wetland habitat or not connected to the lake).

The locations of the sites that are scheduled to be sampled in 2021 by bird and anuran field crews stretch from the Duluth-Superior harbor area and extend 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 will require access by boat.

Fish, Macroinvertebrates, and Water Quality:
NRRI maintains 4 core staff to supervise, coordinate, and lead field teams during wetland surveys. NRRI intends to hire 2 summer technicians to aid the GLCWMP in the NRRI region. Summer technicians receive advanced training to perform biological surveys, which are skills invaluable to them as they seek long-term employment. Presently, the NRRI team intends to visit 26 wetlands in 2021: 12 wetlands in the Lake Superior basin, and 14 within the Lake Michigan basin. Two of the sites are designated as benchmarks, five are resamples, and four are pre-sample sites where restorations activities are planned for the near future. 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. We learned a lot about traveling and conducting field work safely during the 2020 field season. We are hopeful the 2021 field season will be more ‘normal’ as more of the U.S. population is vaccinated against Covid-19 and it becomes safer to travel.

Aquatic Macrophytes:
26 wetlands along Lake Superior and Lake Michigan will be sampled in summer 2021. The professional botanists Ryne and Jenny Rutherford who have carried out UWS vegetation sampling in previous years will sample 22 sites located east of Superior Wisconsin. Dr. Jeremy Hartsock will assist at some of these sites. Four wetland sites located in proximity to Superior Wisconsin will be sampled by UWS crew members Jeremy Hartsock, Reed Schwarting, and Kelly O’Brien Beaster. Vegetation surveys will be completed in teams of two. It is hoped all UWS sampling crew members will receive COVID-19 vaccinations before field work begins. Nonetheless, face masks will be worn in the presences of other crew members at all times.

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 2021. 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 SOPs).

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

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

Sample Processing and Data Entry (2020)

Central Michigan University:
From October 1st, 2020 through March 31st, 2021, 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 2020 bird and anuran field survey data have been uploaded and QC'd in the database. All 2020 plant data have been entered into the database and have been checked by crew leader Allison Kneisel. Additionally, Dr. Albert has performed a final check on all 2020 vegetation data.

100% of 2020 fish and macroinvertebrate field data have been entered and checked by a second person. 100% of 2020 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.

Lake Superior State University:
Data entry for all parameters, including water quality, chl a, and benthic macroinvertebrates, has been entered and all data have been checked following the QA/QC procedures. We did complete 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.

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 2020 field season was completed in March 2021 (and those data were entered and checked for quality control in late March 2021). 100% of the 2020 field data have been entered; 100% have been checked by a second person. 100% completion of macroinvertebrate identification for samples collected during the 2020 field season; 100% of 2020 macroinvertebrate data have been entered. Macroinvertebrate sample exchange with CMU was completed in March 2021.

University of Notre Dame:
Field-collected data (fish, habitat, etc.) and laboratory parameters (chlorophyll-*a*) have been entered and 100% QC'd. 100% of 2020 macroinvertebrate samples have been identified, entered, and QC'd. Macroinvertebrate sample exchange is in progress.

Analysis of 142 chlorophyll-*a* filter samples from various CWMP partners [CMU, GVSU, LSSU, UWN, CWS-ON (Environment Canada)] has been completed. Results have been dispersed to all partners for data entry. We followed the standard 90% buffered acetone extraction protocol with acidification and then analyzed samples in the dark using a spectrophotometer.

Interesting results from 2020

Blanding's turtles (*Emydoidea blandingii*), a species of concern in Michigan, were captured in our fyke nets near Crow Island SGA in site 524 (Saginaw Bay River; Figure 29). We found European frogbit (*Hydrocharis morsus-ranae*), an invasive species, at site 7075 (Shiawassee Flats) while setting fyke net leads. We did not detect this species last year at this site. We reported it to the Shiawassee National Wildlife Refuge biologist.

Figure 29. Blanding's turtles (*Emydoidea blandingii*), a species of concern in Michigan, were captured in fyke nets at site 524.

Upon review of 2020 data, Dr. Albert noted that European frogbit (*Hydrocharis morsus-ranae*) was found in all three transects of Pentwater River Wetland (site 1301), an eastern Lake Michigan site. This is the first time that vegetation crews have found this invasive species in Lake Michigan, apart from a single observation in Point St. Ignace Wetland (site 1598) in 2019. European frogbit was found in many Upper Peninsula sites in 2020, including those that have been considered high quality, such as Marquette Island (627), and those that are remote, such as Maud Bay (686) and Gogomain River Wetland (833). European frog-bit was not found at these sites in 2015. Invasive hybrid cattail (*Typha* x *glauca*) also appeared to increase in coverage in sites where it was already established, unlike most of the emergent native plants with which it shared habitat.

2021 Field Season Preparations

Site Distribution
Central Michigan University received the 2021 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 the crews, the central basin crew was assigned 52 sites. One site was rejected because it could not be accessed due to Covid-19 border closure. Three of the remaining 52 sites were benchmark sites. There is ongoing restoration/reconnection taking place at one benchmark site and two sites are benchmarked due to their low and high quality, respectively. Of the 52 sites to be sampled in the summer of 2021, 29 were assigned to Central Michigan University, 7 were assigned to the University of Notre Dame, 7 were assigned to Grand Valley State University, and 9 were assigned to Lake Superior State University. Central Basin crews are planning a field training event in early-June at site 515 to ensure consistency and competency among crews.

Central Michigan University Aquatic Macrophyte Crew:
Allison Kneisel and Matthew Sand will lead the 2021 vegetation surveys under the direction of Dr. Albert. An additional field crew leader will be CMU graduate student Olivia Anderson, who is a returning 2020 crew member. Crew members will be trained in sampling protocols and plant identification in late June of 2021.

After trades, the central basin vegetation crew was assigned 55 sites, two of which have already been rejected due to the US-Canadian border being closed. Among the remaining sites, there are four benchmark sites: Two are part of long-term sampling efforts and two are being sampled to track impacts of high-water levels.

CMU Fish, Macroinvertebrate and Habitat Crew:
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 Anuran and Bird Crew:
Site selection for 2021 currently includes 46 wetland sites to survey for anurans and birds. One of those sites will not be sampled (not safely accessible). The remaining 45 sites are located in northern and eastern Lake Michigan, southern and western Lake Erie, and northern and western Lake Huron. Two 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 18th March, 2021. Crew members have been tested and certified for identification of frog and toad calls and proper field procedures. Anuran surveys will likely begin by late March 2021, dependent on temperature and safety concerns. Training for bird surveys, procedures, and certification of bird identification will occur in April 2021, prior to sampling.

Lake Superior State University:
LSSU has been assigned 9 sites for 2021 and is getting prepared to sample all of those assigned. Current travel restrictions across the border continue to be a concern for future field work, but at this point we have not been assigned any Canadian sites.

Reporting to the MDNR for the scientific collector's permit was completed in early March and the 2021 scientific collector's permit was received as well. This month announcements were posted for summer crew positions and interviews were completed at the end of February and hires were completed the first week of March. The crew is planning a training session with CMU, GVSU, and Notre Dame in early June to ensure the crews' competency in all parts of the project.

Grand Valley State University:
The GVSU crew plans to visit the seven sites that were assigned for the 2021 field season. GVSU will continue to coordinate with the CMU, LSSU, and UND crews and will attend the June 8-9 field training days, hosted by CMU, prior to the start of our 2021 fieldwork. Sampling will likely begin the week of June 14-18 and last through the end of July 2021.

We are in the process of completing our annual DNR Collectors Permit report for fish sampling (for the 2020 field season), and Dr. Ruetz is in the process of applying for a scientific collector's permit to sample fish for the 2021 field season. Dr. Ruetz is also in the process of submitting our annual IACUC report for the 2020 field season. Matthew Silverhart will serve as the field crew lead for the GVSU crew in 2021. We are in the process of hiring two undergraduates as technicians to assist with sampling in the 2021 field season.

University of Notre Dame:
Notre Dame has been assigned 7 sites to sample during the 2021 field season. These sites fall within the Lake Michigan and Lake Huron basins. We anticipate sampling all sites between June and August 2021. Scientific collectors' permits are in the process of being obtained from the states in which these sites reside, and our IACUC has been renewed.

Katherine O'Reilly and Whitney Conard are returning as rotating field workers and Sarah Klepinger will act as crew leader. One additional grad student (Alison Zachritz) will also help us in the field as needed. For the 2021 field season, we will also hire one full-time seasonal field technician. Due to COVID-19 concerns, we are unable to attend a training session with other Central Basin crews, but we will independently field-test the protocols with our full crew at a site near campus.

Other Activities

CMU postdoc Anna Harrison has two papers in preparation for publication using CWMP data and one on-going project. Dr. Harrison is currently incorporating the 2020 water quality data into a manuscript entitled, "Status and trends of water quality in Great Lakes coastal wetlands - a basin-wide analysis from 2011-2020", to be submitted by summer 2021. This paper broadly describes water quality trends across the basin over the ten years of CWMP sampling and investigates local drivers of human-driven water quality disturbance.

Dr. Harrison is also collaborating with USGS on a fish community and seasonal trends paper, to be submitted in spring 2021, entitled "Functional assessment of Great Lakes coastal wetlands: insights from seasonal fish communities." This paper details seasonal fish community variation in GL coastal wetlands across spring, summer, and fall from 2016-2018.

CMU graduate student Derek Hartline is currently working on updating our macroinvertebrate indices of biotic integrity to include additional vegetation zones as part of his Master's thesis using 2011-2020 CWMP macroinvertebrate and water quality data.

Three Lake Superior State University crew members will be working on their undergraduate projects in conjunction with the GLCWMP this summer. Avery Feldmeier will be sampling multiple wetlands (3-4) throughout the summer to determine the stability of IBIs in St. Marys River wetlands. Savanah Blower will be comparing macroinvertebrate communities across different shoreline types (e.g., hardened vs naturally vegetated), and Michael Hillary is going to be conducting litter decomposition studies in the wetlands to compare functional indicators to biological indicators.

Eastern U.S. Regional Team: Katie Amatangelo (Lead, Macroinvertebrates), Chris Norment (Birds and Anurans), Rachel Schultz (Aquatic Macrophytes), Matt Altenritter (Fish) and Michael Chislock (Water Quality)

Sample Processing, Data Entry, and Quality Control Checks

The SUNY Brockport aquatic macroinvertebrate personnel, overseen by Dr. Kathryn Amatangelo and Gregory Lawrence, completed 100% of all macroinvertebrate identification and quality control checks from 2020 sampling. Dr. Michael Chislock and students in the limnology and Environmental Laboratory Approval Program (ELAP)-certified water quality lab at SUNY Brockport completed 100% of laboratory water quality analyses and quality control checks. Graduate and undergraduate technicians, overseen by Dr. Kathryn Amatangelo, Dr. Rachel Schultz, Dr. Matthew Altenritter, and Gregory Lawrence, entered and performed quality checks on all other data from the 2020 sampling season, including all bird, anuran, fish, water quality, and vegetation data.

2020 Benchmarks and Data Sharing

SUNY Brockport continued to sample sites within the Rochester Embayment Area of Concern as benchmarks to aid ecological monitoring for restoration projects. Cranberry Pond (site 50) was sampled as a benchmark site in 2020 to supplement pre-restoration monitoring for an upcoming National Fish and Wildlife Foundation (NFWF)-funded restoration project completed by National Audubon Society and Ducks Unlimited in early 2021. This project aims to reduce invasive cattail (*Typha* spp.) cover and improve habitat for marsh birds and waterfowl, along with spawning areas for northern pike (*Esox lucius*).

Braddock Bay (site 7052) was again sampled as a benchmark site in 2020 to supplement U.S. Environmental Protection Agency-Great Lakes Restoration Initiative (USEPA-GLRI)-funded post-restoration data collection for the U.S. Army Corps of Engineers (USACE) restoration project completed in 2018. This project aimed to reduce wave attack, wetland loss, and turbidity by re-creating the lost barrier beach, and reduced invasive cattail cover and included pothole and channel creation to provide spawning and nursery areas for northern pike and habitat for black terns (*Chlidonias niger*) and waterfowl.

Lastly, SUNY Brockport worked with various invasive species removal crews and local agency partners such as New York State Department of Environmental Conservation (NYSDEC), Finger Lakes Partnership for Regional Invasive Species Management (PRISM) and Genesee Valley Audubon Society, by providing sightings and information on invasive plant and animal infestations. Reports of invasive species, particularly water chestnut (*Trapa natans*), directly led to these organizations' rapid response crews eradicating the infestations from the wetlands in efforts to restore native wetland vegetation communities at these sites.

Working with Partners in 2020

SUNY Brockport worked with a handful of partners during 2020 using Great Lakes Coastal Wetlands Monitoring Program (GLCWMP) sampling to assist local restoration projects. Data from fish, bird, and anuran sampling at Braddock Bay were summarized and included in SUNY Brockport's report to the NYSDEC, USEPA, and USACE to provide post-restoration data on ecological conditions at Braddock Bay to help NYSDEC and local partners 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 the organization can use in pre-restoration evaluation of the project site. GLCWMP data continue to assist USEPA-GLRI-funded projects and will help target and guide future restoration projects in Great Lakes coastal wetlands.

SUNY 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 crews found in multiple sites on the south shore of Lake Ontario. Finger Lakes PRISM, NYSDEC, and volunteer groups mobilized and removed water chestnut at these sites and will continue to monitor them after detections by SUNY Brockport GLCWMP crews. Further, crews detected and reported other aquatic invasive plants of interest, such as starry stonewort (*Nitellopsis obtusa*).

2020 Observations

2020 was another good year for focal bird species, with 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*) 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) and Buck Pond (51).

The vegetation crew found some interesting plants, including sundew (*Drosera rotundifolia*), cranberry (*Vaccinium macrocarpon*), bayberry (*Morella carolinensis*) and other unique peatland species at Cranberry Pond (50). The fish crew had a banner year for painted (*Chrysemys picta*) and snapping turtles (*Chelydra serpentina*). Fish highlights included many young-of-year bowfin (*Amia calva;* Figure 30), and numerous northern pike (*Esox lucius*).

Figure 30. Bowfin (*Amia calva*) from Second Creek (7028).

2021 Site List and Crew Assignments

SUNY Brockport has finalized its 2021 site list and is beginning preparations to have the bird and anuran survey crews ready to sample when temperatures increase, likely in mid-April. Braddock Bay (site 7052), Cranberry Pond (site 50), and Stony Creek Marsh (site 133) have received benchmark designations. Sampling at Braddock Bay will continue to supplement USEPA-GLRI funded post-restoration data collection for the USEPA-GLRI-funded restoration project completed by USACE in 2018. Sampling at Cranberry Pond will provide post-restoration data for the NFWF-funded restoration project completed by National Audubon Society and Ducks Unlimited in early 2021. Further, sampling at Stony Creek Marsh (site 133) will help boost the sample size of wetland sites at the ends of the environmental gradient. Stony Creek Marsh (site 133) was identified as one of the higher quality sites according to index of ecological condition (IEC) scores for birds and anurans, but has not been sampled for fish, vegetation, water quality, or aquatic invertebrates. Adding the site as a benchmark will help evaluate other taxa and water quality and get a better picture of its overall wetland condition and add a higher quality site to our sampling regime.

SUNY Brockport has worked with neighboring crews at Environment and Climate Change Canada, University of Windsor, and University of Wisconsin-River Falls to swap sites and ensure that as many sites are sampled across the basin as possible. Due to travel restrictions to Canadian sites resulting from COVID-19 response guidelines, SUNY Brockport received four sites in Ohio in western Lake Erie that will be sampled by fish, aquatic macroinvertebrate, water quality, and vegetation crews. No additional sites were picked up for bird and anuran crews.

SUNY Brockport personnel have applied for and are awaiting access permits for sites from the NYSDEC, New York State Office of Parks, Recreation, and Historic Preservation, and Ohio Department of Natural Resources. Training and required certifications will be completed this spring for all crews.

Canadian and US Western Lake Erie Regional Team: Jan Ciborowski, Joseph Gathman (Water Quality, Fish and Macroinvertebrates), Carla Huebert (Aquatic Macrophytes), Doug Tozer (Birds and Anurans), and Joe Fiorino (north shore of Lake Ontario – Water Quality, Fish, Macroinvertebrates, Aquatic Macrophytes)

Sample Processing and Data Entry (2020)

All field data collected during the 2020 field season have been uploaded and QC'd. Specimens are being exchanged with one of the two companion labs (part of the reciprocal exchange of macroinvertebrate specimens to ensure consistency of identification). Samples received in previous years have been identified and returned to the sample owners. All fish, macroinvertebrate, macrophyte and water-quality data collected in 2020 were compiled and entered into the database and quality assured over the winter.

2020 Significant Observations:

Birds and Anurans:
Of note were 126 point occurrences of 9 Ontario bird species at risk (Table 19). Also of note were 8 occurrences of Chorus Frog, which is listed as threatened in Canada (vs. 10 occurrences in 2019).

Table 19. Ontario bird species at risk seen in 2020 wetland sampling.

		No. Occurrences	
Species	**ON-ESA/SARA Status***	**2019**	**2020****
Bald Eagle	special concern	23	11
Bank Swallow	threatened	16	12
Barn Swallow	threatened	62	59
Black Tern	special concern	14	7
Bobolink	threatened	1	3
Chimney Swift	threatened	4	2
Common Nighthawk	threatened	2	4
Eastern Meadowlark	threatened	1	3
King Rail	threatened	1	0
Least Bittern	endangered	25	25
Total		149	126

*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 2020 are preliminary due to incomplete data entry; occurrences for some species will increase once data entry is complete.

Fishes and Invertebrates

Non-native Round Gobies were found by the CWS team at three of the 10 sites fished on Lake Ontario: South Bay Marsh 2 (5922), Adolphustown Marsh 2 (5005) and Sand Bay 2 (5856). Tubenose Gobies were also caught at Adolphustown and Sand Bay. Tubenose Gobies are less common and have only been reported in the east end of Lake Ontario. Common Carp were captured at Adolphustown and Rattray Marsh (5799). Common Carp were much less abundant at Rattray Marsh than in the previous year sampled; over 400 individuals were captured in 2018 while less than 10 were seen in 2020. Round Gobies were collected at 3 locations in Lake Huron (Baie du Dore on the Bruce Peninsula; Port McNicholl Marsh 2 and Victoria Harbour Marsh in Severn Sound), and at 3 Lake Erie sites (Long Point Wetland 7 [5545], Flat Creek Wetland (5304), and Hillman Marsh). Tubenose Gobies were caught at Old Fort St. Joe Point (5702), on St. Joseph's Island, Victoria Harbour Marsh (6011), and Port McNicholl Marsh 2 (5769) on Lake Huron. Common Carp were captured at one wetland on Lake Erie (Turkey Point Wetland [6001]) and one in Lake Huron (Sadler Creek Wetland 1 [5844]).

Other ***s***pecies of note observed during the 2020 field season included two Grass Pickerel (Special Concern under the Species at Risk Act) captured at Wellers Bay 6 (6039). Warmouth caught at Flat Creek Wetland and Turkey Point Wetland; and a Spotted Gar, collected at Hillman

Marsh (5422). Additionally, a Northern Sunfish (*Lepomis peltastes*) was caught at Port McNicholl Marsh 2 (5769) on Lake Huron.

Notes on Water Levels and their Influence on Sampling

Water levels in lakes Erie and Huron were historically high in 2019, and levels were comparable in 2020. Vegetation zones continued their multi-year trend of altering distributions up-slope in conjunction with the higher levels. As in 2019, this influenced our ability to set fyke nets, and in some locations necessitated sampling macroinvertebrates from boats rather than by wading (see below). As noted in previous years, some sites continue to exhibit reductions in the extent of monospecific stands and a greater prevalence of species interspersion, including many open areas where little or no emergent vegetation is present. This appears to be a consequence of high water thinning out the wet meadow vegetation while dense stands of cattail and other emergent vegetation persist further down-slope in deeper water and seem to be slow to expand up-slope into the previous meadow areas (also see below). Several sites in 2020 had the same emergent vegetation "islands", usually bulrush or cattail, where the meadow was either completely submerged or drastically reduced in size, thereby eliminating the gradual transition of vegetation downslope from meadow to emergent zones. As a result, there was a large dead zone consisting of little to no vegetation between the shoreline or meadow (if still present), and the emergent zone. Pumpkin Point 2 and Old Fort St. Joe Point (both North Channel) had examples of this.

The high water resulted in the emergent and wet meadow zones of sites having enough water to be fished but most sites were again limited to one or two fishable zones because most other vegetation zones were too deep to fish.

Lake Ontario water levels resembled the long-term average in 2020. However, there were instances where the only suitable vegetation zones were too deep for sampling fishes. One site (East Lake Marsh 5) could not be fished at all due to a combination of high water levels and unconsolidated sediment that exceeded the feasibility of the deep water fishing protocol. Additionally, most sites had significant patches of floating cattail (*Typha)* mats that were difficult to traverse and slowed surveying. Despite this, all vegetation surveys were completed for all sites.

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 throughout the 2020 sampling season, although the channel has narrowed. Both the north and south ends of the east beach at the breach have developed sand spits adjacent to one another, with the more northern spit extending westward into the marsh as well as eastward into the lake. The channel opening meanders through these two peninsulas. Staff at Point Pelee National Park (Tara Degazio) have indicated that there are no plans to try and close the breach.

Storms in 2019 also eroded the barrier beach separating Hillman Marsh from the main lake. Furthermore, significant erosion was reported along the shoreline separating Rondeau Bay from the north shore of Lake Erie proper. Our teams were unable to survey the condition of these areas in 2020. These three areas presently comprise almost the entire range of Spotted Gar and Warmouth, which are species-at-risk in Canada.

Monitoring Short-term Variation in Dissolved Oxygen and Water Levels
In 2020, we continued a study begun in 2018 to assess day-night variability in wetland dissolved oxygen, temperature and water levels to investigate the possible influence of these variables on samples of aquatic invertebrates and catches of fishes in fyke nets. We deployed one or more Onset Hobo dissolved oxygen (DO) loggers and light temperature recorders at the location of each fyke net in each wetland. In addition, we used Onset Hobo water level loggers at a single site within each wetland. Data were recorded every 15 minutes over a period of 18-24 h, depending on the duration of the fyke net sets. We anticipate that these loggers will provide us with information on daily DO maxima and minima, which will help define the environmental suitability of areas for mobile fishes and the likelihood of capturing them. Similarly, water level data will help us record seiche effects, which may influence both the abundance and composition of fish species in wetlands (e.g. Trebitz 2006). CWS teams deployed water level and DO loggers at six sites and 8 zones (on 1 net per zone) visited in Lake Ontario. Loggers were left overnight and retrieved when the nets were pulled the following day.

University of Windsor Research Assistant Anique Gauvin is receiving and compiling the basin - scale water level data collected by participating CWM teams for 2020. We are still receiving records from the various CWM groups. In Canada, water level records were collected from 26 wetlands (6 on Lake Ontario, 5 on Lake Erie and 15 on Lake Huron). We have also received information on 11 wetlands collected by Central Michigan University crews. Colleagues from other CWM teams will also contribute data from late season sampling efforts.

Reptiles
In Ontario, six turtle species occurring in the Great Lakes are listed as at risk under the *Species at Risk Act* (SARA): Spotted Turtle (*Clemmys guttata*) [Endangered]; Blanding's Turtle (*Emydoidea blandingii*) Great Lakes/St. Lawrence population, Spiny Softshell Turtle (*Apalone spinifera*) [Threatened], 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 project of the Great Lakes Restoration Initiative (GLRI), as well as other sources of turtle observations were used to identify many suitable habitat locations in Ontario as critical habitat. The data provided from CWM Program 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.

The Windsor and CWS teams recorded both inadvertent catches of turtles in fyke nets and sightings observed during vegetation sampling. In all, the following turtles were observed by the CWS and University of Windsor teams:

- Eastern Snapping Turtles (*Chelydra serpentina*) were recorded at four of 10 Lake Ontario wetlands that were fished, one individual in each wetland: Big Island Marsh, Blessington Creek Marsh, Rattray Marsh, and South Bay Marsh.

- Painted Turtles (*Chrysemys picta*) were the most widespread species, with specimens caught at 14 locations.

- Two Northern Map turtles (*Graptemys geographica)* were observed at Pont au Baril 9 (Georgian Bay of Lake Huron), and 8 Northern Map turtles were seen at Cedar Creek (Lake Erie).

This year, our vegetation crew also recorded all sightings of snakes during their surveys. One Northern Watersnake was observed at Point au Baril 9, and 2 Northern Watersnakes were seen at Sadler Creek Wetland 1. One Eastern Garter Snake was found at Sadler Creek 5.

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. In 2020, delineating between vegetation zones continued to pose a challenge, as

the species that normally are found in monoculture are becoming increasingly found mixed with other species. In addition the continuing flooding of meadows has increased the frequency of finding plants more typical of the emergent and submergent zones. Furthermore, sedges and other meadow species could be found growing far out into what should be the emergent zone.

The continuation of record high lake levels in 2020 has resulted in further thinning of some types of emergent vegetation. The gaps between meadow species and more flood-tolerant emergent species (cattails, bulrushes) are filling 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, one year after the record high water levels of 2019, there were perceptible changes in vegetation community structure. The CWS team noted that on the lakeward side of the cattail zone there were significant floating mats at some sites (e.g., East Lake), whereas other sites showed evidence of erosion (e.g., South Bay). Qualitatively, there also seemed to be a larger transitional zone between cattail and meadow vegetation compared to previous years, likely the result of extremely high water levels in two of the previous three years allowing cattail to expand further upland.

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; few meadow species are able to persist when the water levels rise and remain at levels as high as they have been for the past several years. During sampling this year, it was 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, being able to withstand and grow in water depths of up to 1 m or more.

We observed a sizeable mat of the Species-at-Risk (Status: Threatened) American Water-willow (*Justicia americana*) growing at the mouth of East Cranberry Pond (Point Pelee National Park), approximately 500 m from the breach. While this species is adapted to fluctuating water levels, high wave action from a northeast storm event pushing through into the wetland could impact this population, as well as the small pockets of *Justicia* located on the edges of the cattail mats nearby in Lake Pond. In addition, Swamp Rose Mallow (*Hibiscus moscheutos*) (Status: Special Concern) was found at Point Pelee and at 3 other Lake Erie sites this year: Flat Creek Wetland (Rondeau Bay), Cedar Creek, and Hillman Marsh.

Range expansions of Invasive Plant Species

Starry Stonewort *(Nitellopsis obtuse)*

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. CWS noted that *N. obtusa* is becoming increasingly abundant in Lake Ontario wetlands, with large, dense monodominant patches present at some sites (that occasionally impede travel by boat) (e.g. Sawguin Creek, South Bay). In 2020 we also found this species for the first time at a Lake Huron site, Port McNicholl Marsh 2, located in the Severn Sound area. This site was previously sampled in 2015 but *N. obtusa* was not observed at that time.

Phragmites *(Phragmites australis)*

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

No new wetland records of P*hragmites australis* were observed in 2020. 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. Invasive *Phragmites australis* was found again in 2020 at one North Channel site (Site 5790 Pumpkin Point 2). This site was sampled in 2019, when *Phragmites* had been found for the first time at that site. The stand has not increased in size in 2020, possibly because the stand is situated in relatively deep water (125 cm) distant from the shoreline. In 2019, the density of stems was low enough that the stand could easily be paddled through, and it remained that way in 2020.

Another small, sparse stand of invasive *Phragmites,* originally found in 2015, was observed again in one of our Severn Sound sites, (Site 5769, Port McNicholl Marsh 2). As was the case for the Pumpkin Point site (above), the stand was situated in deep water (150 cm), relatively far from shore, and the density was low enough that the stand could be traversed by canoe.

Four of our six sampled Lake Erie wetlands had been sprayed and treated for invasive *Phragmites* since the last time they were sampled 5 years ago, in 2015. These include: Flat Creek Wetland, Turkey Point Wetland, Long Point Wetland 7, and Cedar Creek (last sampled 4 years ago, in 2016). Turkey Point Wetland (sprayed and treated in 2018) had the most noteworthy change, likely due to the exposed, muddy sand flats that are dotted throughout this wetland. Several uncommon species of *Cyperus* (Flatsedge), *Echinochloa* (Barnyard Grass), and *Eleocharis* (Spike-Rush) were found growing on these muddy sand flat habitats, which were formerly part of a huge P*hragmite*s monoculture.

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, which expose shorelines less frequently than a naturally fluctuating system. One substantial stand of invasive *Phragmites* was observed at one site by CWS in 2020 (Wellers Bay 4).

<u>Water Chestnut *(Trapa Natans)*</u>
With the recent arrival of another aquatic invasive plant,*Trapa natans*, to wetlands located at the inflow of the St. Lawrence River, eastern Lake Ontario wetlands could become increasingly affected by aquatic invasive species in the near future. Ongoing efforts such as the CWM project are critical to identifying sites for management and restoration in addition to providing important information to better understand the potential impacts and provide surveillance of these species. In 2020, CWS did not observe *T. natans* at any site on Lake Ontario.

<u>European Frog Bit *(Hydrocharis morsus-ranae)*</u>
There were no observations of range extension of European Frog Bit into new northern wetlands in 2020. European Frog Bit continues to be abundant at many Lake Ontario wetlands.

This was the first year during which we sampled numerous Canadian Lake Erie wetlands that have been recently treated for *Phragmites.* In some parts of these sprayed wetlands, Carla Huebert observed an interesting phenomenon: The eradication of dense stands of *Phragmites* created sunny, open spaces that are overgrown with dense Frog Bit mats. Ironically, the effective control of one aggressive invasive species has allowed another equally aggressive invasive to take its place.

<u>European Water Horehound *(Lycopus europaeus)*</u>

European Water Horehound (*Lycopus europaeus*) was conclusively observed for the first time in 2020 at several wetlands in lakes Ontario, Erie, and Huron. In Lake Ontario, it was found at three sites: Turtle Creek- Reed Swamp (6002), Grafton Swamp (5358), and Colborne Creek 1 (5179)). In Lake Erie, it was found at two sites: Point Pelee Marsh 2 (5762) and Hillman Marsh (5422). In Lake Huron, it was found at only one site, in Severn Sound: Port McNicholl Marsh 2 (5769), the same site at which Starry Stonewort was found this year.

Prior to 2020, *Lycopus europaeus* had not been observed at any of our wetlands, so either conditions in 2020 were favourable for the development of European Water Horehound or the species' range is expanding. This species is a member of the mint family and it was not dominant in any of the quadrats in which it was recorded, but was definitely present where it had not been before. There are no existing reports of this species in wetlands sampled by the University of Windsor team. Specimens of *Lycopus sp.* were observed at Muddy Creek (site 5654) Lake Erie in 2016, but the fruits were not developed at the time of surveying so species identity could not be determined. Mature specimens were found this year in part because surveys were conducted later in the season than is typical because of delays due to the COVID-19 pandemic.

Field Training

Many of the individuals who will participate in fieldwork in 2021 were involved in sampling during the 2020 and earlier field seasons. Consequently, only refresher training will be undertaken for them. No new recruits will be joining the Tozer anuran-and-bird team. Anuran and bird surveys will be attempted at 58 sites and will begin shortly, as soon as overnight temperatures are above 5°C. 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 2021 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 at the western end of Lake Ontario presently allocated to the Canadian Wildlife Service team.

All members of the 5-person Windsor field crew from 2020 will be involved in field work in 2021. Depending on COVID-related restrictions, they will train 1-2 new senior undergraduate students and orient new co-investigator Dr. Paul Weidman, who will assist during selected field trips. The Canadian Wildlife Service will have 6 personnel to conduct work on Lake Ontario in 2021: four staff with several years of field experience and training on the project, and two coop 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 collecting 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.

We anticipate that continuing high-water conditions on Lake Erie and Lake Huron will result in our use of the revised fish/invertebrate sampling guidelines that we implemented in 2020. Accordingly, all crew will be fully trained in both these new guidelines and in the revisions outlined in the 2021 QAPP. As was done last year, we will collect invertebrate samples even in zones that exceed one-meter in depth, when possible. Where water is too deep to allow sampling on foot, we will sample from a boat, using D-nets with telescoping handles. Similarly, if we are unable to locate zones under one-meter in depth, then we will use the deep-set fishing method, meaning that the fyke nets will be fully submerged. As in 2020, we will sample SAV zones, but only when there are no other zones to sample.

Returning team members Marie-Anique Gauvin, and Stephanie Johnson and CWS team members Joe Fiorino and Ian Smith 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 refreshers in field and lab safety training. Vegetation survey training will be led in early June by team leader Carla Huebert near Windsor, ON and by CWS team leader Joe Fiorino near Toronto, ON. Vegetation assistants will be introduced to the specific vegetation sampling methodology and data recording methods outlined in the QAPP.

2021 Sites and Field Preparation

New sites for 2021 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 2021. However, given the continuing risks of COVID 19 transmission, we expect that our requests for access to First Nations lands will be denied.

Sampling for fishes in Canada requires approval by the University of Windsor's Animal Use Care Committee as well as permits for Scientific Collection of Aquatic Species (Ontario Ministry of Natural Resources), compliance with the Province of Ontario's Environmental Protection Act

(Ontario Ministry of Natural Resources), and Species At Risk (Fisheries & Oceans Canada). Fish sampling on the Ohio shores of Lake Erie requires a Wild Animal Collection permit (Ohio Department of Natural Resources), and sampling in National Wildlife Refuges in Ohio requires permits from the US Fish and Wildlife Service. Permit renewal applications are in progress to ensure approval by the start of the sampling season. Reports to the permit granting agencies for 2020 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 analysed by graduate student Jeffrey Buckley (M.Sc. 2015) to compare the consistency of classification of wetland condition using analytical metrics derived by several different investigators. Buckley compared the 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 MS will be submitted in 2021.

Danielle Gunsch (M.Sc 2020) estimated diel dissolved oxygen cycles and the associated invertebrate and fish fauna along an elevation/depth gradient 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 were greater between regions (North Channel of Georgian Bay vs. Bruce Peninsula wetlands) than along the elevation/depth gradient within each wetland. Significant differences in abundance of some taxa (coenagrionid damselflies, *Gammarus and Hyalella* amphipods, and flatworms were observed along 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. 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 2020, Stephanie Johnson 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 2020, 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 also contributed data from selected 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 37 sites by 3 CWMP teams during their fish sampling periods in 2020. Dissolved oxygen records were collected for 26 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 (M.Sc. 2021) analysed data from fyke net catches and water-level and dissolved-oxygen loggers deployed in two Lake Erie wetlands over much of the sampling season. Fyke nets captured fished during both seiche and calm weather periods in each wetland to estimate the importance of seiches on fish abundance and community composition estimates. 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 nighttime calm periods resulted in rapid anoxia as water flowed from shallow, emergent areas into the main wetland. In one small wetland, onshore wind drove oxygen-rich lake water into the wetland allowing immigration (and fyke net captures) of large, lake-dwelling fishes. When these events were followed by hot, calm nights, water became anoxic and resulted in significant overnight mortality of trapped fishes. In contrast, the larger water volume of a riverine wetland largely dampened the effects of seiches on changes in dissolved oxygen concentration and fish catches.

Tara Hohman (M.Sc. 2019) in collaboration with all of the anuran and bird PIs analyzed the program's entire bird dataset and reported new findings of wetland bird community changes at broad scales in relation to changing water levels throughout the entire Great Lakes basin. Tara's results indicate that water extent and interspersion increased in coastal wetlands across the Great Lakes between low (2013) and high (2018) lake-level years, although variation in the magnitude of change occurred within and among lakes. Increases in water extent and interspersion resulted in a general increase in marsh-obligate and marsh-facultative bird species richness. Species like American Bittern, Common Gallinule, American Coot, Sora, Virginia Rail, and Pied-Billed Grebe were significantly more abundant during high water years. Lakes Huron and Michigan showed the greatest increase in water extent and interspersion among the five Great Lakes, while Lake Michigan showed the greatest increase in marsh-obligate bird species richness. These results reinforce the idea that effective management, restoration, and assessment of wetlands must account for fluctuations in lake levels. Although high lake levels generally provide the most favorable conditions for wetland bird species, variation in lake levels and bird species assemblages create ecosystems that are both spatially and temporally dynamic. The team published Tara's results in the *Journal of Great Lakes Research* available here [https://doi.org/10.1016/j.jglr.2021.01.006].

All of the bird and anuran PIs in collaboration with a large team of scientists from National Audubon and Audubon Great Lakes analyzed the program's entire bird dataset from the U.S. portion of the Great Lakes and developed a spatial prioritization to identify the most important U.S. Great Lakes coastal wetlands for 14 marsh bird species. We modeled occurrence and relative abundance of each species using boosted regression trees, a machine learning algorithm, to relate standardized monitoring data to ten remotely-sensed environmental covariates. We then used Zonation conservation planning software to rank every wetland cell based on its importance for the suite of marsh bird species. Evaluation of the drivers of marsh bird occurrence and abundance revealed that open water, herbaceous wetland, latitude, longitude, and impervious surface were the most important predictors across focal species. The high-priority wetlands for marsh birds (defined as grid cells ranked in the top 20%) occurred along the shores of eastern Lake Ontario, western Lake Erie/St. Clair, Saginaw Bay, Green Bay, northern lakes Michigan and Huron, and western Lake Superior. Overall, less than half (42%) of high priority coastal wetlands across the Great Lakes basin are currently under some level of protection, with Lake Ontario priority wetlands being the least protected (25%). Our findings represent an opportunity to improve coastal wetland conservation in a region where wetland loss and degradation continue to threaten marsh bird populations and the integrity of one of the world's largest freshwater ecosystems. The team published these findings in *Biological Conservation* available here [https://doi.org/10.1016/j.biocon.2020.108708].

Building Interactions with Stakeholders and Collaborators

We have been building a multi-year working relationship with Point Pelee National Park (PPNP).

In 2020, we attempted to sample Lake Pond in PPNP to provide Park personnel with additional pre-restoration baseline information relating to the implementation of a vegetation-removal exercise meant to reduce *Phragmites* and *Typha* encroachment and improve hydrological connectivity among several connected waterbodies. This work is also helping to identify the changes that have occurred as the result of a breach in the protective sand-spit cause by high lake levels. The breach created in summer 2018 between Lake Pond and the east shore of Lake Erie continued to permit water exchanges and contributed to continuing high water levels. We will extend our sampling to include 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.

In 2020, we conducted detailed analysis of CWM information in collaboration with the Detroit River Canadian Cleanup (DRCC) group (responsible for Canadian waters of the Detroit River Area of Concern): CWMP data on fishes, aquatic invertebrates, vegetation and water quality were combined with other data collected by various consortia to determine criteria by which to delist several Beneficial Use Impairments. Using CWMP information from all available sites on Lake Erie and in the St. Clair-Detroit River system, were able to identify benchmarks in biological condition that have been adopted by the DRCC to assess Impaired Beneficial Uses #2 (Macroinvertebrates), #3 (fishes) and #11 (Aquatic Habitat). We found that bird IEC as well as IBI scores are informative in assessing thresholds in the amount of agricultural vs. developed land in watersheds. We also identified fish and invertebrate IBI index benchmarks. However, they reflected local water quality independently of habitat condition *per se* (Ciborowski et al. 2020).

Plans to sample collaboratively with Katrina Keeshig and Clint Jacobs of the NinDaWaabJig Heritage Centre at Bkejwanong Territory (Walpole Island First Nation) in 2020 were deferred due to the COVID 19 pandemic. We will continue our dialog in anticipation that we will eventually be able to sample this area, which contains some of the most pristine wetlands in the lower Great Lakes.

In 2021, the Canadian Wildlife Service requested and received permission for the Meteorological Services of Canada to use *Phragmites australis subsp. australis* and *Typha spp.* data from the CWMP between years 2011 and 2019 for Lakes Ontario, Huron, and Erie to model the distribution of *Phragmites* and *Typha* through time in response to key physical variables (e.g. water levels) under carbon emission scenarios. These models are integral to a climate change vulnerability assessment for 20 Great Lakes coastal wetland sites and will improve the understanding of climate-related impacts on these important ecosystems across the basin. The results of the vulnerability assessment will be used to inform resilience strategies and mitigation actions for coastal wetlands under climate change.

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 are revising the QAPP and SOPs for round 3 sampling to ensure that everything is understandable and the QAPP matches the SOPs.

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 2020 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 contract lab (used for 2020 samples because the National Lab was closed due to Covid-19). Laboratory results from 2020 have passed the criteria shown below (Table 20) or were excluded from the database.

Table 20. Data acceptance criteria for water quality analyses.

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

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

Variability in Field Replicates:
An analysis of field duplicate variability for each year of the program through 2019 is shown in Table 21. The table could not be updated for 2020 data due to the lateness of some of that data being added to the database because of Covid-19 shutdowns to labs. 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 21 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 limits and low spatial variability; therefore, these values had much lower average RPD. Acceptance of data associated with higher-than-expected RPD was determined by the QA officers. The maximum expected RPD values are based on the MN Pollution Control Agency quality assurance project plan provided for the Event Based Sampling Program (http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/surface-water-financial-assistance/event-based-sampling-grants.html#for-grantees).

Table 21. Field duplicate sample variability for 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 program ends its tenth year (fifth year of round 2 sampling). Nearly all program members virtually attended an all-hands Zoom program organizational meeting on February 12, 2021. Holding the meeting virtually meant that field and laboratory technicians and grad students could attend without worrying about having a travel budget. The PIs discussed issues pertaining to the upcoming field season and how we would continue dealing with Covid 19 issues and border closures, dealing with high Great Lakes water levels, manuscript topics, and report products. Individual taxonomic teams held their meetings virtually within a week of the overall program meeting.

Regional team leaders and co-PIs have held many conference calls and e-mail discussions regarding fieldwork, 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 changed last year depending on the field crew and PI, and may again be different this field season depending on Covid-19 guidance from states and universities and vaccination status of PIs and field crews. However, again this year 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. We are very proud of what our field crews accomplished safely last year despite a global pandemic and having to navigate continually changing guidance from the CDC and each individual university and state. Crews sampled safely, accurately, and without spreading Covid-19. 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 (including a global pandemic), and to conduct that sampling in accordance with strict QA procedures.

LEVERAGED BENEFITS OF PROJECT (2010 – 2020)

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, CMU, and others, is investigating the drivers that influence water column chlorophyll-*a* in coastal wetlands. Our hypothesis is that chlorophyll-*a* will be related to nutrient status of wetlands and degree of development of adjoining land. 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* in coastal wetlands 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 Creak Wetland as part of an Environmental Impact Assessment related to a proposed Confined Animal Feeding Operation upstream of the wetland.

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

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

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

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

Student Research Support

Graduate Research with Leveraged Funding:

- Updating Dr. Gerald Mackie's key to Sphaeriidae (fingernail clams) of the Great lakes as informed by DNA analyses (University of Minnesota Duluth in collaboration with GLRI-funded work at Central Michigan University, the laboratory of Dr. Andrew Mahon).
- Importance of coastal wetlands to offshore fishes of the Great Lakes: Dietary support and habitat utilization (Central Michigan University; with additional funding from several small University grants and the US Fish and Wildlife Service).
- Spatial variation in macroinvertebrate communities within two emergent plant zones in Great Lakes coastal wetlands (Central Michigan University; with additional funding from CMU).
- Invertebrate co-occurrence patterns in coastal wetlands of the Great Lakes: Community assembly rules (Central Michigan University; additional funding from CMU)
- Functional indicators of Great Lakes coastal wetland health (University of Notre Dame; additional funding by Illinois-Indiana Sea Grant).
- Evaluating environmental DNA detection alongside standard fish sampling in Great Lakes coastal wetland monitoring (University of Notre Dame; additional funding by Illinois-Indiana Sea Grant).
- Nutrient-limitation in Great Lakes coastal wetlands (University of Notre Dame; additional funding by the UND College of Science).
- A summary of snapping turtle (*Chelydra serpentina*) by-catch records in Lake Ontario coastal wetlands (with additional funding by University of Toronto).
- Evaluating a zoobenthic indicator of Great Lakes wetland condition (with additional funding from University of Windsor).

- Testing and comparing the diagnostic value of three fish community indicators of Great Lakes wetland condition (with additional funding from GLRI GLIC: GLEI II and University of Windsor).
- Quantifying Aquatic Invasion Patterns Through Space and Time: A Relational Analysis of the Laurentian Great Lakes (University of Minnesota Duluth; with additional funding and data from USEPA)
- Novel Diagnostics for Biotransport of Aquatic Environmental Contaminants (University of Notre Dame, with additional funding from Advanced Diagnostics & Therapeutics program)
- Conservation of Common Terns in the Great Lakes Region (University of Minnesota; with additional funding from USFWS, MNDNR, and multiple smaller internal and external grants).
- Distribution of yellow perch in Great Lakes coastal wetlands (Grand Valley State University; with additional funding from GVSU).
- Variation in aquatic invertebrate assemblages in coastal wetland wet meadow zones of Lake Huron, of the Laurentian Great Lakes (University of Windsor; with additional funding from the University of Windsor).
- Influence of water level fluctuations and diel variation in dissolved oxygen concentrations on fish habitat use in Great Lakes coastal wetlands (University of Windsor; with additional funding from the University of Windsor).
- 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)
- Updating the Macroinvertebrate-based Index of Biotic Integrity for Great Lakes coastal wetlands (Central Michigan University)

Undergraduate Research without Leveraged Funding:

- Sensitivity of fish community metrics to net set locations: a comparison between Coastal Wetland Monitoring and GLEI methods (University of Minnesota Duluth).
- Larval fish usage and assemblage composition between different wetland types (Central Michigan University).
- Determining wetland health for selected Great Lakes Coastal Wetlands and incorporating management recommendations (Central Michigan University).
- Invertebrate co-occurrence trends in the wetlands of the Upper Peninsula and Western Michigan and the role of habitat disturbance levels (Central Michigan University).
- Is macroinvertebrate richness and community composition determined by habitat complexity or variation in complexity? (University of Windsor, complete; 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.
- Understanding drivers of chlorophyll-a in Great Lakes coastal wetlands. University of Notre Dame

Jobs Created/Retained (2020):

- Principal Investigators (partial support): 22
- Post-doctoral researchers (partial support): 4
- Total graduate students supported on project (part-time): 19
- Unpaid undergraduate internship (summer): Not possible in 2020 due to Covid-19
- Undergraduate students (paid; summer and/or part-time): 21
- Technicians, jr. scientists (summer and/or partial support): 39
- Volunteers: Could not have volunteers in 2020 due to Covid-19

Total jobs at least partially supported in 2020: 105.

Students and post-doctoral researchers trained in 2020: 44.

Jobs Created/Retained (cumulative since 2011):

- Principal Investigators (partial support): 20 (average per year)
- Post-doctoral researchers (partial support; cumulative): 7
- Total graduate students supported on project (part-time; cumulative): 113
- Unpaid undergraduate internship (summer, cumulative): 35
- Undergraduate students (paid; summer and/or part-time; cumulative): 194
- Technicians, jr. scientists (summer and/or partial support; cumulative): 135
- Volunteers (cumulative): 47

Total jobs at least partially supported: 469.
Students and post-doctoral researchers trained: 349.

At our annual meeting in 2021, we conducted a formal discussion session on Diversity, Equity, and Inclusion (DEI). The approximately 70 meeting participants were split randomly into 10 breakout groups to discuss three questions related to best practices for enhancing DEI in the CWMP workforce. In brief, the three questions concerned 1) current practices used to enhance DEI, 2) perceived barriers to enhancing DEI, and 3) potential mechanisms for enhancing DEI in the future. After discussion, the breakout groups returned to the main meeting session for discussion of findings as reported by a group spokesperson. A useful discussion then ensued of best practices (past, current, and future) for diversifying the CWMP workforce to achieve the goal of a workforce representative of the U.S. population as a whole. A scribe for each group then submitted written points to the meeting organizers. These comments were compiled and organized, and then redistributed to all CWMP participants. CWMP leadership will continue to monitor and encourage DEI goals for the program.

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.

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Appendix

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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.