Great Lakes Coastal Wetland Monitoring Program

Semiannual Progress Report

April 1, 2021 – September 30, 2021

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INTRODUCTION

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

We have completed two five-year rounds of monitoring and this summer embarked on year 2 of the third five-year sampling round. This will be our first full sampling round as a sampling program rather than a project. During this second round (2016-2021) we combated high water levels that made wetland sampling challenging and drowned out some wetlands. It appears that Great Lakes water levels are moderating as we begin round 3. In addition, we continue to support wetland restoration projects by providing data, information, and context.

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

Our yearly sampling schedule proceeds in this manner: During the winter, PIs and crew chiefs meet to discuss issues, update each other on progress, and ensure that everyone is staying on track for QA/QC. Sites are selected by March using the on-line site selection database system, and field crew training takes place from March – June, depending on biotic type. Anuran sampling typically begins in late March/early April with bird sampling beginning in April or May, and finally vegetation, fish, macroinvertebrate, and water quality sampling begins in June. Sampling start dates are weather and temperature dependent. 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. Our project management team has not changed.

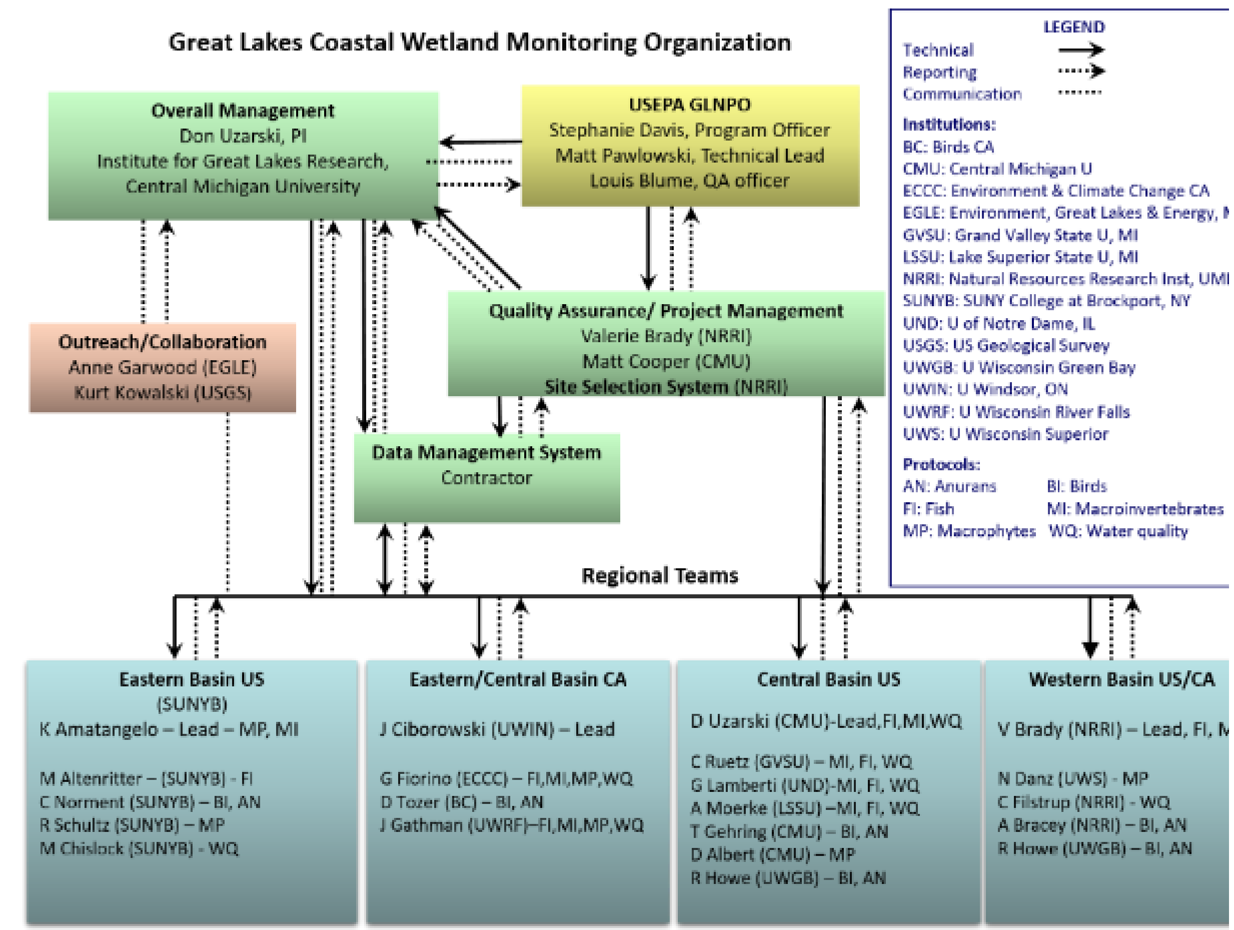

Figure 1. Organizational chart for the program showing lines of technical direction, reporting, and communication separately.

Katie Fairchild is transitioning into the role held by Anne Garwood of Michigan Environment, Great Lakes and Energy (EGLE) to link wetland managers and restoration specialists with GLCWMP data.

PROGRAM TIMELINE

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

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

	2021				2022				2023				2024				2025				2026			
Tasks	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			X																					
PI meeting	X				X				X				X				X				X			
Site selection system updated	X				X				X				X				X							
Site selection for summer		X			X				X				X				X							
Sampling permits acquired		X				X				X				X				X						
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, 2021 – September 30, 2021)		Project Status* (February 2021 – January 2026)	
		Number	Percent	Number	Percent
4.1.3	Number of Great Lakes coastal wetlands assessed for biotic condition	176	20%	176	20%
* (Not Started; Started; Paused; 25% Completed; 50% Completed; 75% Completed; 95% Completed; and 100% Completed)					

SITE SELECTION

Year eleven site selection was completed in March 2021. We have completed our 5-year sampling scheme twice (round 1: 2011-2015; round 2: 2016-2020) and have now begun round 3 (2021-2025) through our list of Great Lakes coastal wetlands. Differences in the site list between successive sampling rounds are most often associated with special benchmark sites or changes due to lake levels and our ability to access sites safely and with permission. Benchmark sites (sites of special interest for restoration or protection) can be sampled more than once in the five year sampling rotation, may need to be sampled in a different year to accommodate restoration work, 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 were able to sample for which biota. The list of wetlands 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 site 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 from the GLCWC GIS coverage 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). That is, these 1014 wetlands became our wetland sampling universe, with minor modifications for benchmark sites, as previously described. See the QAPP for a thorough description of site selection criteria. Note that the actual number of sampleable wetlands fluctuates year-to-year with lake level, continued human activity and safe access for crews. Based on the number of wetlands that proved to be sampleable thus far, we expect that the total number of sampleable wetlands will be between 900 and 1000 in any given year; 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 in 2011 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**	

This wetland coverage shows quite a few more Great Lakes wetlands in the US than in Canada, with an even greater percentage of wetland area in the US (Table 3). We speculate that this is partly due to Georgian Bay (Lake Huron) losing wetlands rapidly due to a combination of glacial rebound and topography that limits the potential for coastal wetlands to migrate downslope with falling water levels and to recover with rising water levels. Another component of this US/CA discrepancy is the lack of coastal wetlands along the Canadian shoreline of Lake Superior due to the rugged topography and geology. A final possibility is unequal loss of wetlands between the two countries, but this has not been investigated.

Strata

Geomorphic classes

Geomorphic classes (riverine, barrier-protected, and lacustrine) were determined for each site in the original coastal wetland GIS coverage. Many wetlands inevitably combine aspects of multiple classes, with an exposed coastal region transitioning into protected backwaters bisected by riverine elements. Wetlands were classified according to their predominant geomorphology. Note that we typically do not revisit or change the class originally assigned to a wetland during our 2011 initial site review process.

Regions

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

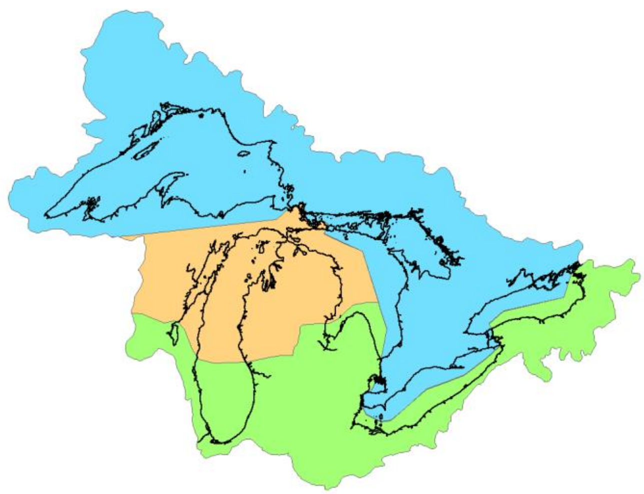

Figure 2. Divisions of lakes into regions. Note that stratification is by region *and* lake, so northern Lake Erie is not in the same region as Lake Superior, etc.

Panelization

Randomization

To create our stratified random wetland site sampling design, the first step was the assignment of selected sites from each of the project's 30 strata (10 regions x 3 geomorphic wetland types) 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. All sites were assigned to panels in 2011, prior to the first round of sampling.

In 2012, sites previously assigned to panels for sampling were assigned to sub-panels for re-sampling. The project’s sampling design requires that 10% of sites are re-sampled the year after they were sampled based on their main panel designation to help determine interannual variability and the effects of changing water levels. This design requires five primary panels, *A-E*, one for each year of a five-year rotation, and ten sub-panels, *a-j,* for the 10% resample sites. 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* was re-sampled in each following year, so the 20 sites in sub-panel *a* of panel *A* were candidates for re-sampling in 2012. The 20 sites in sub-panel *a* of panel *B* were candidates for re-sampling in 2013, and so on. In 2016, panel *A* was sampled for the second time, so the 21 sites in sub-panel *a* of panel *E* became the re-sample sites. This past summer (2021), panel *A* was sampled for the third time and the sites in sub-panel *c* of panel *E* comprised the re-sample sites. 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 is assigned a particular 'workflow' status. During the field season, sites selected for sampling in the current year move through a series of sampling states in a logical order, as shown in Table 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 have more options to indicate problems sampling sites. “Could not access” is used to indicate when a crew cannot safely get to a site for some reason, while “could not sample” is used to indicate the inability to sample a site even though they can get to it (e.g., water is too deep for their sampling gear).

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 is 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 on 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	Indicates site assignment to a team with intent to sample.	0
could not access site	Site proved impossible to access safely.	-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, no wetland present, etc.).	-1
will sample	Interim status indicating field visit confirmed sampleability, but sampling has not yet occurred.	1
sampled	Sampled, field work done.	1
entered	Data entered into database system.	2
checked	Data in database system QC-checked.	3

Browse map

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

2021 Site Selection

For 2021, 218 sites were 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).

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 get a number of requests to provide baseline data for restoration work.

We now have approximately 85 sites for which at least a portion of 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. As has happened each sampling season so far, several teams ended up with fewer sites than they had the capacity to sample, while other teams' assigned sites exceeded their sampling capacity. Within reason, teams with excess sampling capacity expanded their sampling boundaries to assist neighboring over-capacity teams in order to maximize the number of wetlands sampled. The site selection and site status tools are used to make these changes.

TRAINING

All personnel responsible for sampling invertebrates, fish, macrophytes, birds, anurans, and water quality received training and were certified prior to this sampling program beginning in 2011. During that first year, teams of experienced trainers held training workshops at several locations across the Great Lakes basin to ensure that all PIs and crews were trained in Coastal Wetland Monitoring methods. Now that PIs and crew chiefs are experienced, field crew training is being handled by each PI at each regional location, with more experienced trainers providing assistance, including in-person training by the management team, as necessary when major personnel changes take place (e.g., new field crew chief, new PI). As is true every field season, all crew members still had to pass all training tests and mid-season QC were conducted. As has become standard protocol, the trainers were always available via phone and email to answer any questions that arose during training sessions or during the field season.

The following is a synopsis of the training conducted by PIs each spring. See the individual team reports for information on how each team was able to safely yet effectively conduct crew training during the Covid-19 pandemic. Some crews were trained by the crew chief; some crews used only experienced personnel who had worked for the project for years and needed minimal retraining. In general, each PI or field crew chief trained all field personnel on meeting the data quality objectives for each element of the project; this included reviewing the most current version of the QAPP, covering site verification procedures, providing hands-on training for each sampling protocol, and reviewing record-keeping and archiving requirements, data auditing procedures, and certification exams for each sampling protocol. All field crew members had to pass all training certifications before they were allowed to work unsupervised. Those who did not pass all training aspects were only allowed to work under the supervision of a crew leader who had passed all training certifications.

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

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

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

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

Additional training on data entry and data QC was provided by Valerie Brady and Terry Brown through a series of conference calls/webinars during the late summer, fall, and winter of 2011. All co-PIs and crew leaders responsible for data entry participated in these training sessions and each regional laboratory has successfully uploaded data. Additional training on data entry, data uploading, and data QC was provided in 2016 with the implementation of the updated version of the data entry/data archiving system by Todd Redder at LimnoTech. Training on data entry and QC continues via webinar as needed for new program staff and was done in both 2017 and 2018 as new staff joined the program.

Certification

To be certified in a given protocol, individuals must pass a practical exam. Certification exams were conducted in the field in most cases, either during training workshops or during site visits early in the season. When necessary, exams were supplemented with photographs (for fish and vegetation) or audio recordings (for bird and anuran calls). Passing a given exam certifies the individual to perform the respective sampling protocol(s). Since not every individual is responsible for conducting every sampling protocol, crew members were only tested on the protocols for which they are responsible. Personnel who were not certified (e.g., part-time technicians, new students, volunteers) were not allowed to work independently nor to do any taxonomic identification except under the direct supervision of certified staff members. Certification criteria are listed in the project QAPP. For some criteria, demonstrated proficiency during field training workshops or during site visits is considered adequate for certification. Training and certification records for all participants are collected by regional team leaders and copied to Drs. Brady and Cooper (QC managers) and Uzarski (lead PI). Note that the training and certification procedures explained here are separate from the QA/QC evaluations explained in the following section. However, failure to meet project QA/QC standards requires participants to be re-trained and re-certified.

Documentation and Record

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

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

Web-based Data Entry System

The CWMP uses a web-based data management system (DMS) that was originally developed by NRRI in 2011 to collect field and laboratory data, and then redeveloped by LimnoTech during 2015-16. The current web-based system uses 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 vegetation, fish and macronvertebrates, anurans, and birds. Separate data entry/editing forms are created for data entry based on database table schema information that is stored in a separate PostgreSQL schema. Data entry/editing forms are password-protected and can only be accessed by users that have "Project Researcher" or "Admin" credentials associated with their CWMP user account and permissions for specific taxa group(s).

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

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

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

The CWMP data management system also provides separate webpages that allow researchers to download “raw” data for the various taxonomic groups as well as execute and download custom queries that are useful for supporting dataset review and QA/QC evaluations as data entry proceeds during and following each field season. Users from state management agencies are able to access the separate download pages for raw data and custom queries. Such organizations include GLNPO and its subcontractors and Michigan EGLE. Index of Biological Integrity (IBI) metrics are currently included as a download option based on static scores that reflect data collection through the 2020 field season. Over the past few years, a standalone .NET-based program has been developed and fully tested to automate the calculation of IBI metric scores for vegetation, invertebrates and fish on an annual (spring) schedule after data have been entered and gone through QA/QC.

Raw data downloads are available in both Microsoft (MS) Excel spreadsheet and MS Access database formats, while custom query results are available in spreadsheet format only. All available data/query export and download options are automatically regenerated every night, and users have the option of either downloading the last automated export or generating a new export that provides a snapshot of the database at the time the request is made (the former option is much faster). Currently, datasets for the major taxonomic groups must be downloaded individually; however, a comprehensive export of all pertinent data tables is generated in a single MS Access database file and provided to GLNPO on a bi-annual schedule in fall and spring of each program year.

In addition to providing CWMP researchers with data entry and download access, the CWMP data management team is providing ongoing technical support and guidance to GLNPO to support its internal management and application of the QA/QC’ed monitoring datasets. GLNPO, with support from subcontractors, maintains a separate, offline version of the CWMP monitoring database within the Microsoft Access relational database framework. In addition to serving as an offline version of the database, this version provides additional querying and reporting options to support GLNPO’s specific objectives and needs under GLRI. CWMP data management support staff generate and provide to GLNPO and 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 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 4), 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), Round 2 (2016 – 2020) and Round 3 (2021 – 2025) sampling by the Coastal Wetland Monitoring Program. Percentages are of overall total sampled each year. Area in hectares.

Country	Site count	Site %	Site area	Area %
Canada				
Round 1: 2011 - 2015				
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%**
Round 3: 2021 - 2025				
2021	53	30%	4,264	15%
United States				
Round 1 (2011 – 2015)				
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%**
Round 3: 2021 - 2025				
2021	122	70%	24,734	85%
Overall Totals Round 1	**1010**		**151,446**	
Overall Totals Round 2	**978**		**164,312**	
Overall Totals Round 3	**175**		**28,999**	

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 Great Lakes coastal wetlands per year, both by count and by area. However, each year 60-65% of total sites sampled are US coastal wetlands, with 75-80% of the wetland area sampled on the US side. Overall, not yet correcting for sites that have been sampled more than once, we have sampled nearly all of the large, surface-connected Great Lakes emergent coastal wetlands by count and by area. A few wetlands cannot currently be sampled due to safe access or access permission issues.

Teams were able to sample more sites in 2014 due to higher lake levels on Lakes Michigan and Huron, which allowed crews to access sites and areas that have been dry or inaccessible in previous years. By 2015 water depths in some coastal wetlands had become so deep that crews had difficulty finding areas shallow enough to set fish nets in zones typically sampled for fish (cattail, bulrush, SAV, floating leaf, etc.). In 2017 Lake Ontario levels reached highs not seen in many decades. Water levels were again near historic highs in 2019 and 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.

In 2021, water levels had moderated slightly and crews reported fewer difficulties in sampling. The sites sampled in 2021 are shown in Figures 3 and 4 and are color coded by which taxonomic groups were sampled at the sites and by wetland types, respectively. Many sites were sampled for all taxonomic groups. Sites not sampled for birds and anurans typically were sites that were impossible to access safely, often related to private property access issues, or due to pandemic-related border closures. Most bird and anuran crews do not operate from boats since they need to arrive at sites in the dark or stay until well after dark. There are also a number of sites sampled only by bird and anuran crews because these crews can complete their site sampling more quickly and thus have the capacity to sample more sites than do the fish, macroinvertebrate, and vegetation crews.

Because of the Covid-19 global pandemic and because of continued high water, about 25 fewer sites than usual could be sampled during summer 2021. Again this year no field crews were allowed to cross the US-Canada border. In a more typical year, several 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 because no team could get there due to logistics or safety.

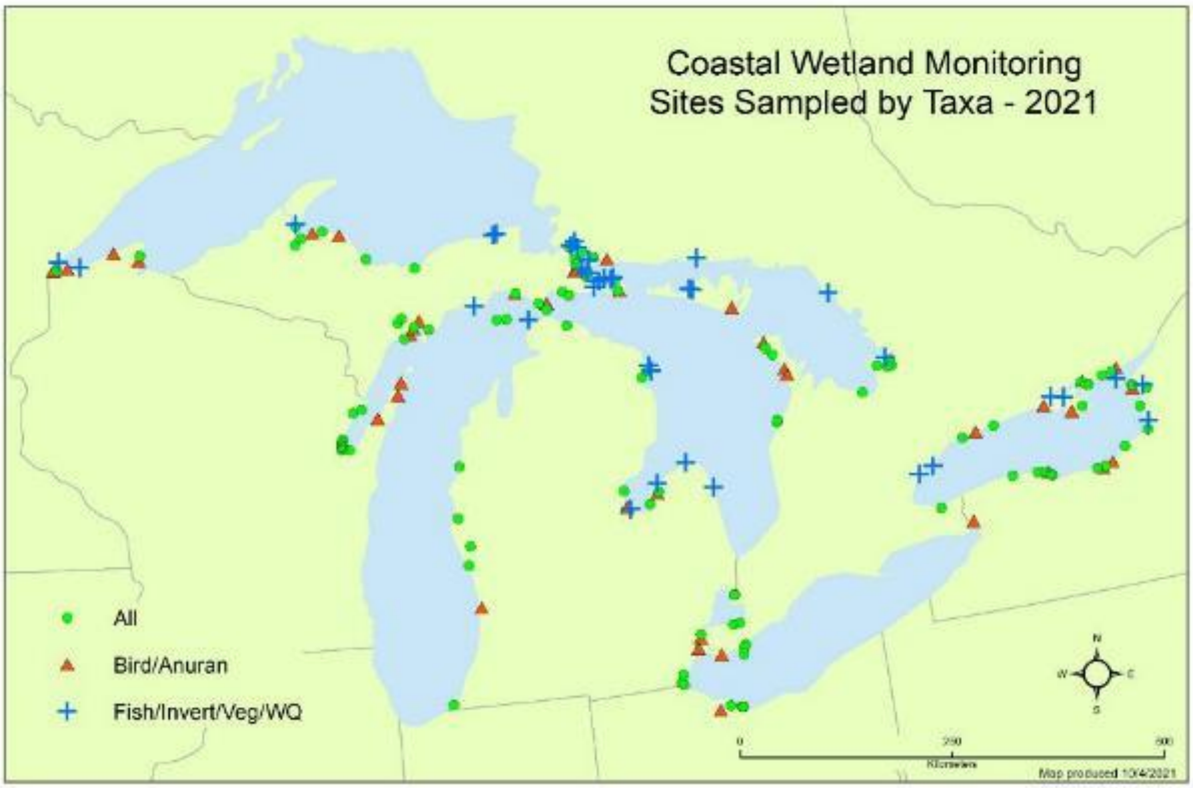

Figure 3. Locations of the 175 Great Lakes coastal wetlands sampled in 2021, color-coded by taxonomic groups. Sites assigned only to bird and anuran crews (due to their greater sampling capacity) are shown with a red triangle.

Wetland types are not distributed evenly across the Great Lakes due to fetch, topography, and geology (Figure 4). Lacustrine wetlands occur in more sheltered areas of the Great Lakes within large bays or adjacent to islands. Barrier-protected wetlands occur along harsher stretches of coastline, particularly in sandy areas, although this is not always the case. Riverine wetlands are somewhat more evenly distributed around the Great Lakes. Low water levels in 2011-2013 and much higher water levels since 2014 require that indicators be relatively robust to Great Lakes water level variations.

Benchmark sites are sites that are 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 get a number of requests to provide baseline data for restoration work.

Figure 4. Locations of the 175 Great Lakes coastal wetlands sampled in 2021, color-coded by site type. Wetland types exhibit a clumped distribution across lakes due to geology and topography.

We now have more than 85 sites that are or have been sampled as a “benchmark.” Of these, 37 are to evaluate restoration efforts and 11 serve as reference sites for their area or for nearby restoration sites. The rest are more intensive monitoring sites at which the extra data will help provide long-term context, help us adjust indicators to be robust against water level fluctuations, and gain better ecological understanding of coastal wetlands. Almost all benchmark sites are in the US.

Determining whether some of these benchmark sites would have been sampled at some point as part of the random site selection process is difficult because several of the exclusion conditions are not easy to assess without site visits. Our best estimate is that approximately 60% of the 17 benchmark sites from 2011 would have been sampled at some point, but they were marked “benchmark” to either sample them sooner (to get ahead of restoration work for baseline sampling) or so that they could be sampled more frequently. Thus, about 40% of 2011 benchmark sites were either added new because they were not (yet) wetlands, are small, or were missed in the wetland coverage, or would have been excluded for lack of connectivity. This percentage decreased in 2012, with only 20% of benchmark sites being sites that were not already in the list of wetlands scheduled to be sampled. In 2013, 30% of benchmark sites were not on the list of random sites to be sampled by CWM researchers in any year, and most were not on the list for the year 2013. For 2014, 26% of benchmark sites were not on the list of sampleable sites, and only 20% of these benchmark sites would have been sampled in 2014. There are a number of benchmark sites that are being sampled every year or every other year to collect extra data on these locations. Thus, we are adding relatively few new sites as benchmarks each year. These tend to be sites that are degraded former wetlands that no longer appear on any wetland coverage but for which restoration is a goal or, in a few cases, wetlands that are diked and the dike is being breached for restoration.

Biotic Communities and Conditions (based on 2016-2020 data)
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. The following indicators and information are from 2020 and will be updated again in the spring of 2022.

Wetlands contained 24 to 29 bird species on average; some sampled benchmark sites had only a couple of bird species, but richness at high quality sites was as great as 64 bird species (Table 7). There are many fewer calling amphibian species (anurans) in the Great Lakes (8 total), and coastal wetlands averaged about 4 species per wetland, with some benchmark wetlands containing no anurans (Table 7). However, there were wetlands where 8 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).

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).

	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).

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.

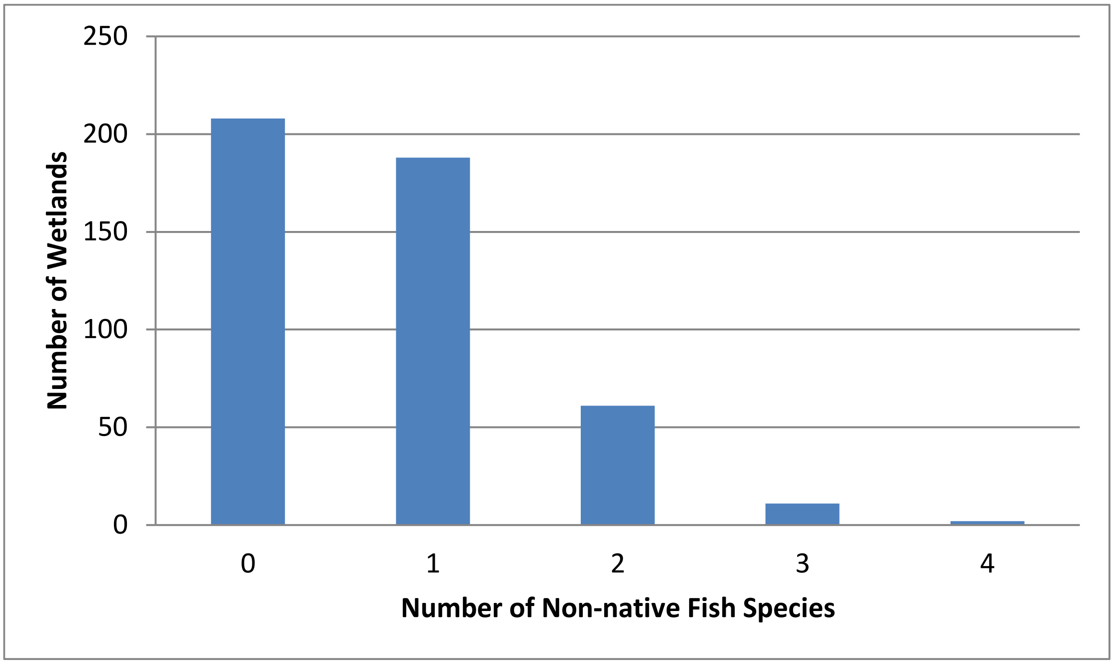

Figure 5. Number of Great Lakes coastal wetlands containing non-native fish species. Data from 2016 through 2020.

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).

		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).

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.

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.

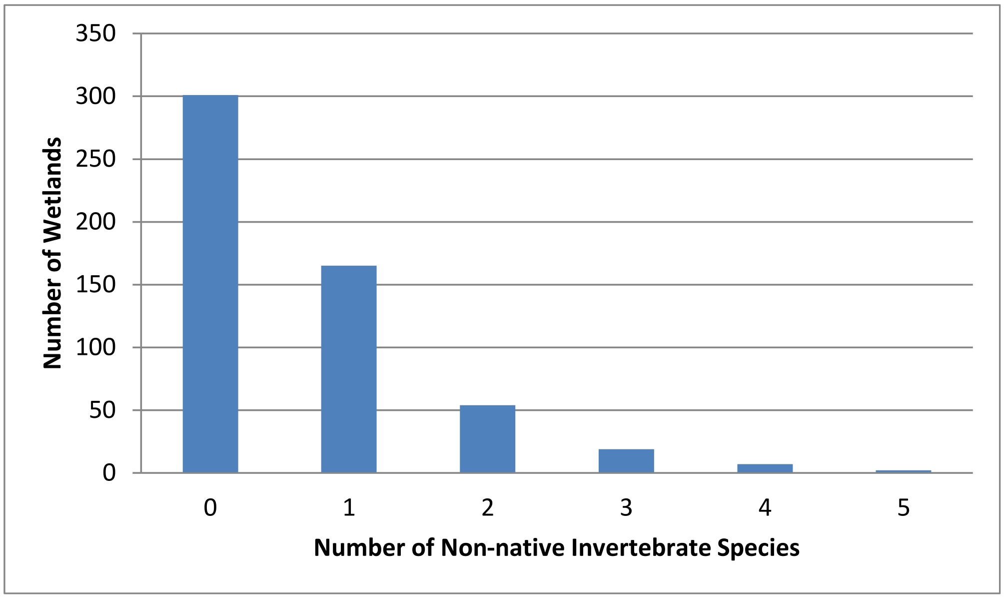

Figure 6. Number of Great Lakes coastal wetlands containing non-native invertebrate species. Data from 2016 through 2020.

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.

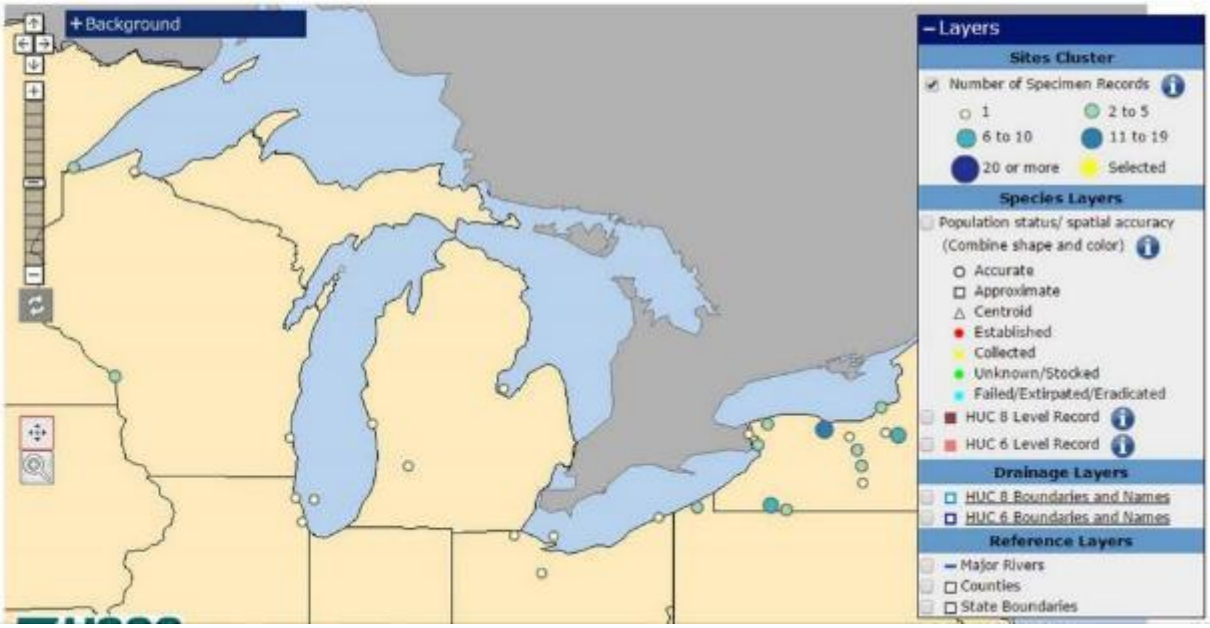

Figure 7. Locations of *Bithynia tentaculata* in USGS NAS website PRIOR to our project providing additional locations where they were collected.

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).

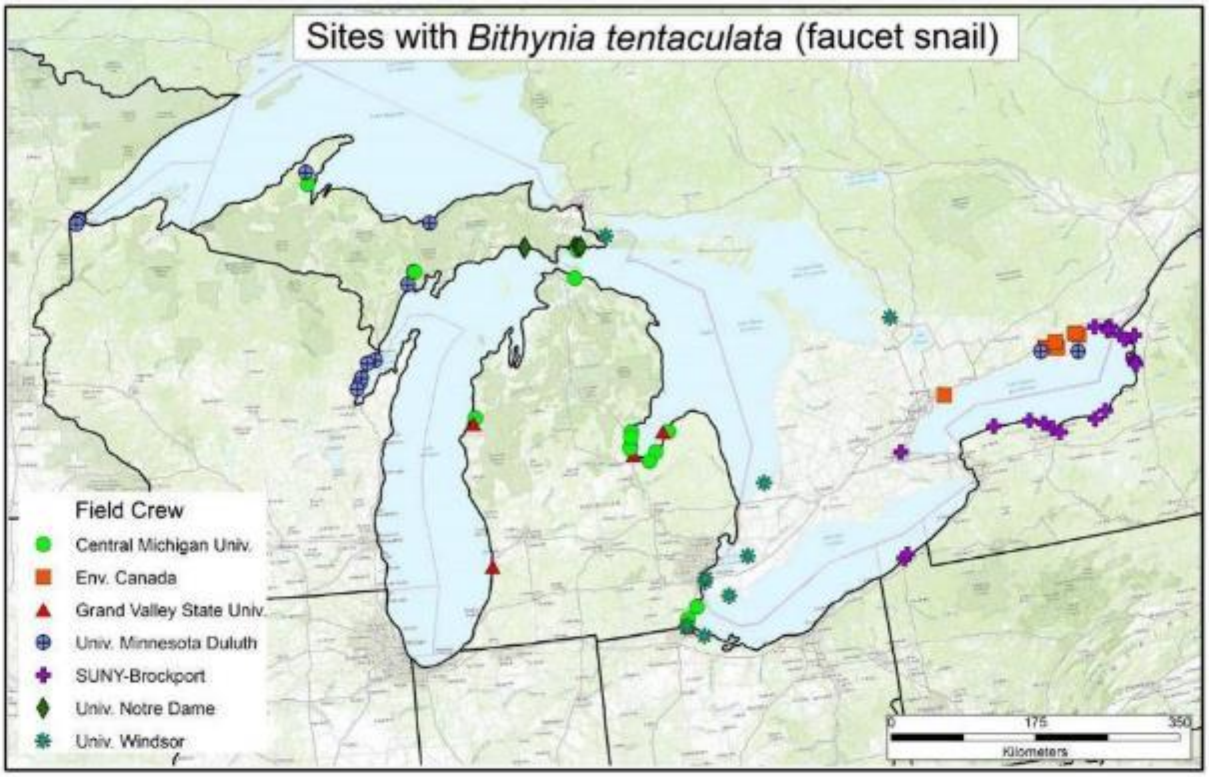

Figure 8. Locations of *Bithynia tentaculata* found by CWM crews, 2011 - 2013.

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

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.

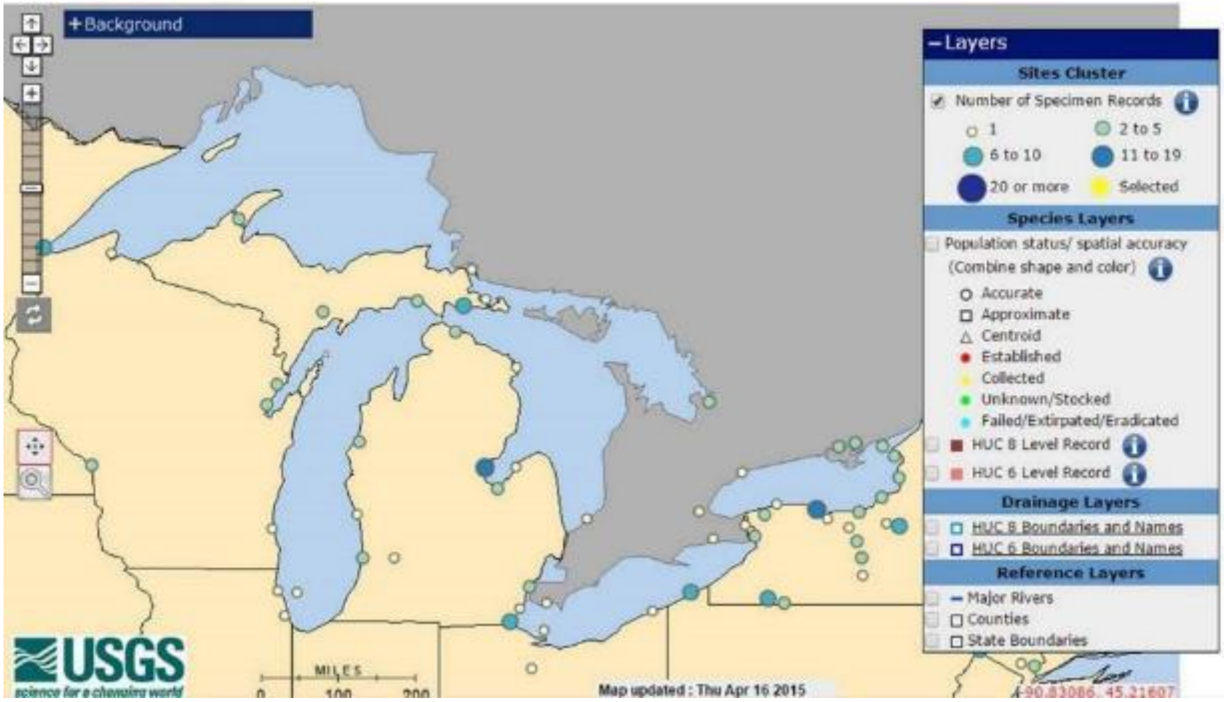

Figure 9. Locations of *Bithynia tentaculata* in USGS NAS website AFTER our project provided additional locations where they were collected; compare to Figure 6.

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).

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).

		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.

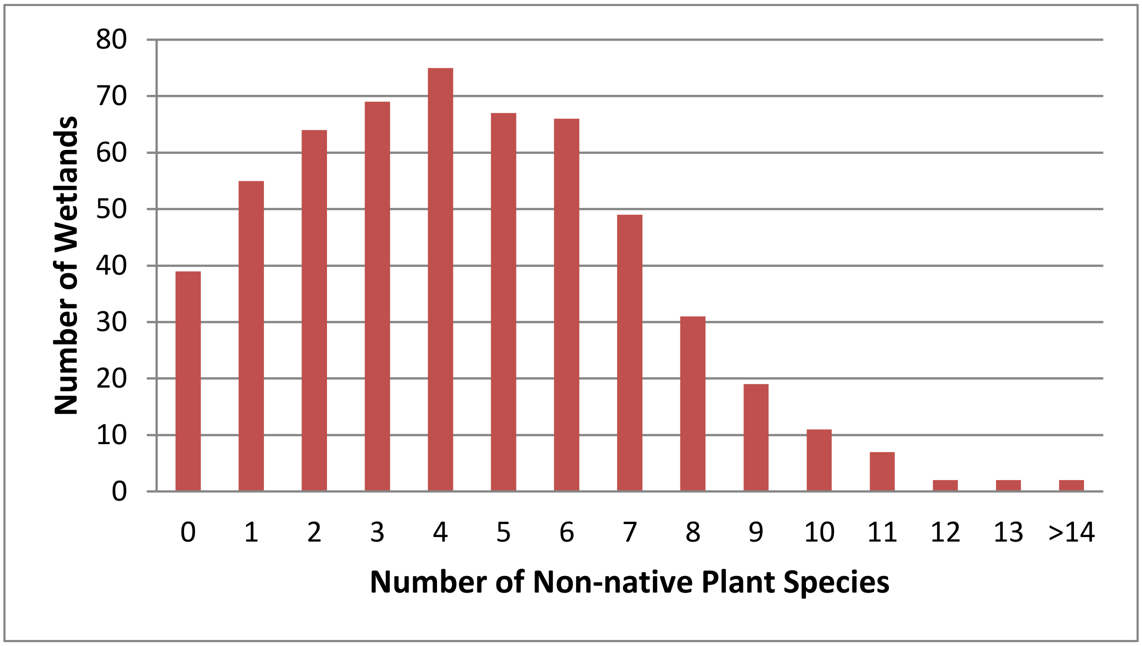

Figure 10. Number of Great Lakes coastal wetlands containing invasive plant species based on 2016 through 2020 data.

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

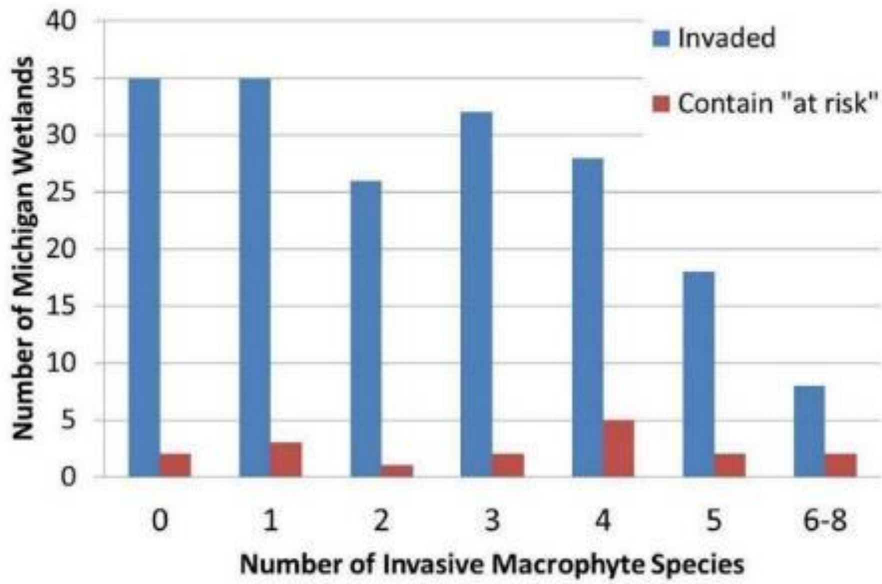

Figure 11. Number of state of Michigan Great Lakes coastal wetlands containing both invasive plant species and “at risk” plant species, based on 2011 through 2014 data.

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

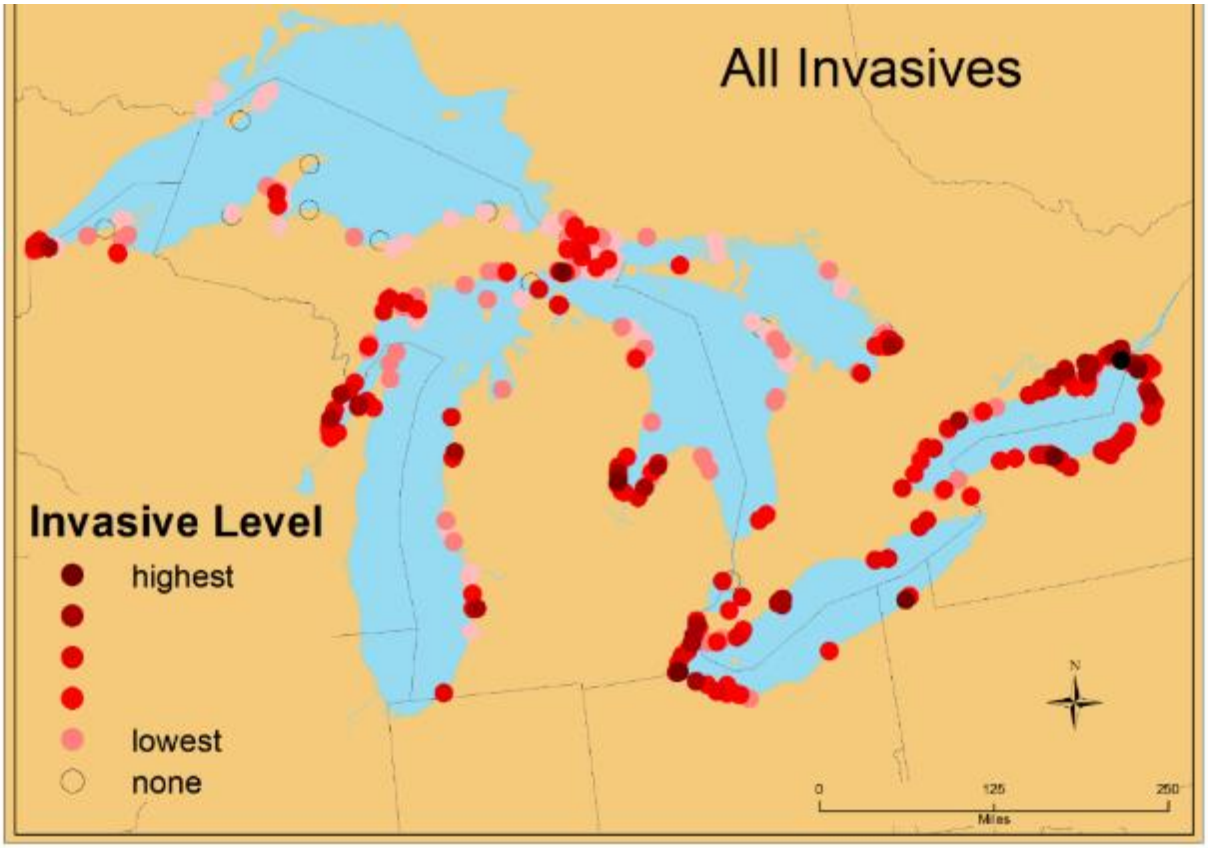

Figure 12. Level of “invadedness” of Great Lakes coastal wetlands for all non-native taxa combined across all taxonomic groups, based on data from 2011-2014.

Wetland Condition (based on 2016 – 2020 data)
In the fall of 2012 we began calculating metrics and IBIs for various taxa. We are evaluating coastal wetland condition using a variety of biota (wetland vegetation, aquatic macroinvertebrates, fish, birds, and anurans).

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

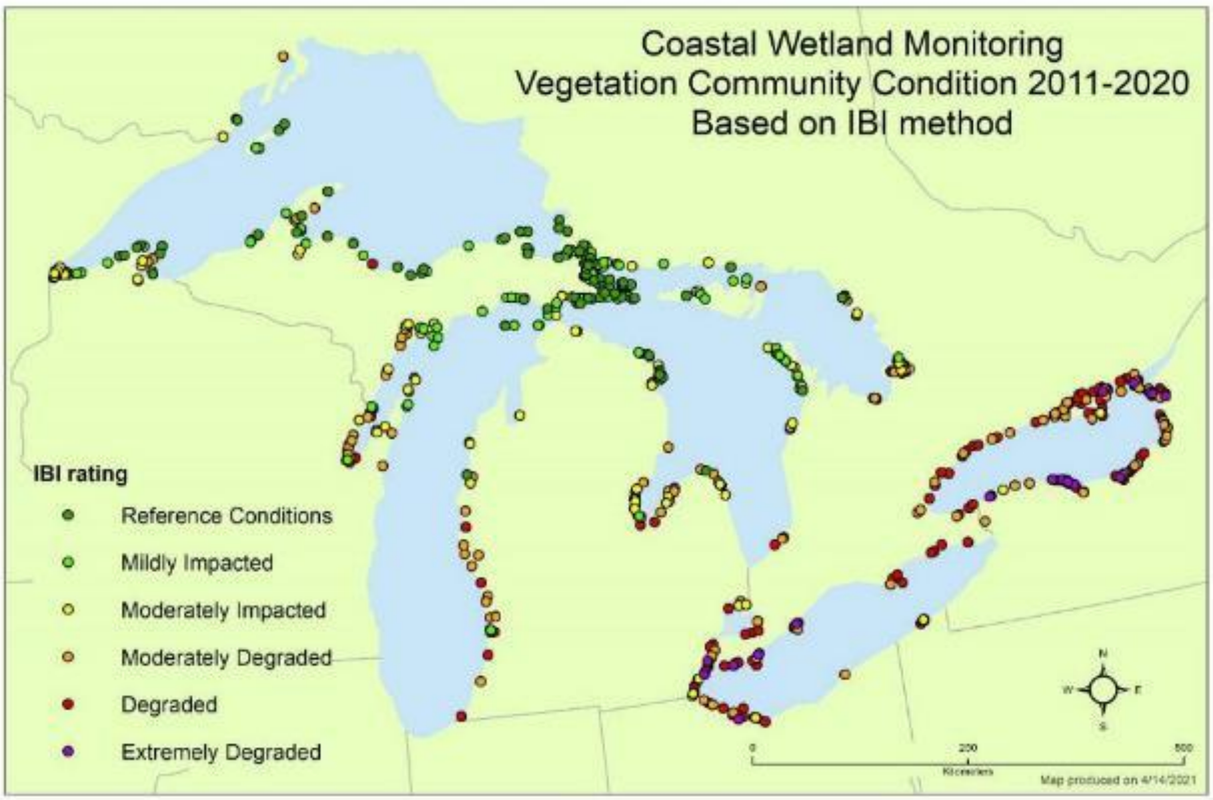

Figure 13. Condition of coastal wetland vegetation at sites across the Great Lakes. Circle color indicates vegetation community quality. The indicator is labeled “draft” while this indicator is investigated for robustness against varying water levels and latitude. Based primarily on data collected between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

Sites with low FQI scores are concentrated in the southern Great Lakes, where there are large amounts of both agriculture and urban development, and where water levels may be more tightly regulated (e.g., Lake Ontario), while sites with high FQI scores are concentrated in the northern Great Lakes. Even in the north, an urban area like Duluth, MN may have high quality wetlands in protected sites and lower quality degraded wetlands in the lower reaches of estuaries (drowned river mouths) where there are legacy effects from the pre-Clean Water Act era, along with nutrient enrichment or heavy siltation from industrial development and/or sewage effluent. Benchmark sites in need of restoration will also have lower condition scores.

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.

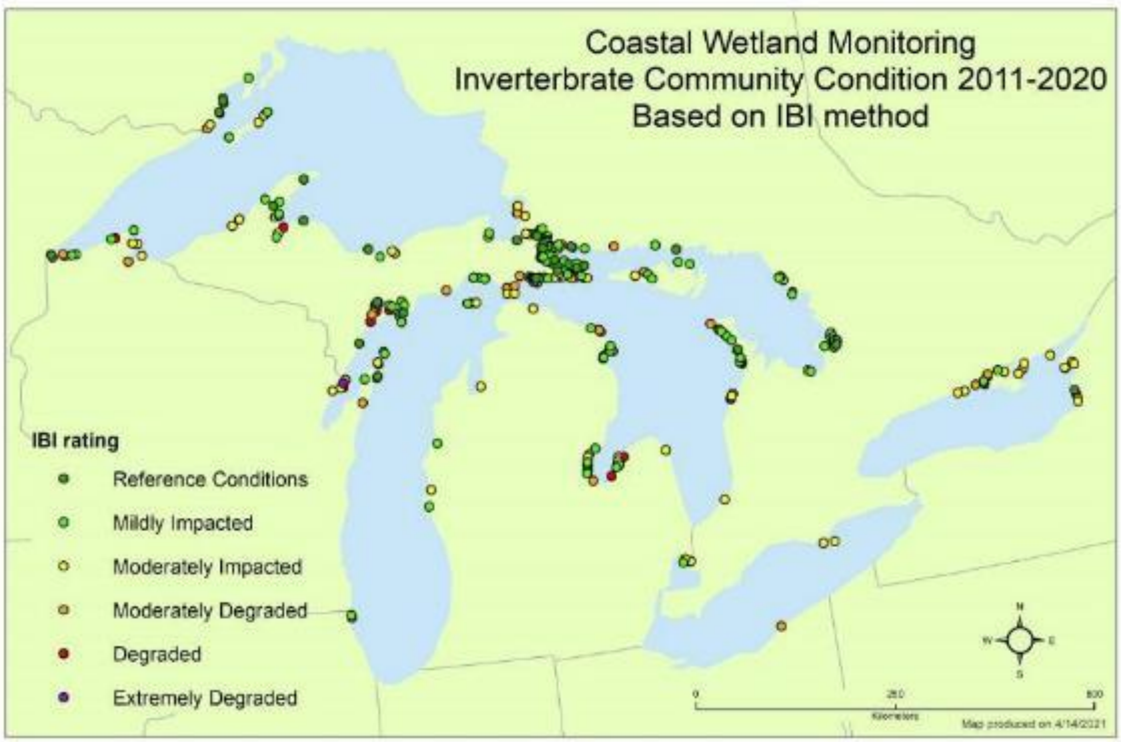

Figure 14. Condition of coastal wetland macroinvertebrate communties at sites with bulrush or wet meadow zones. Based primarily on data collected between 2016 through 2020 with data from 2011-2015 used for sites that were only sampled in those years.

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 zones that GLCWC used to develop and test the invertebrate IBI. Many areas contain dense cattail stands (e.g., southern Green Bay, much of Lake Ontario), for which we do not yet have a published macroinvertebrate IBI. We are developing IBIs for additional vegetation zones to cover these sites, but these IBIs have not yet been validated so they are not included here.

We are now able to report updated and improved fish IBI scores for wetland sites containing bulrush, cattail, lily, or SAV zones (Figure 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.

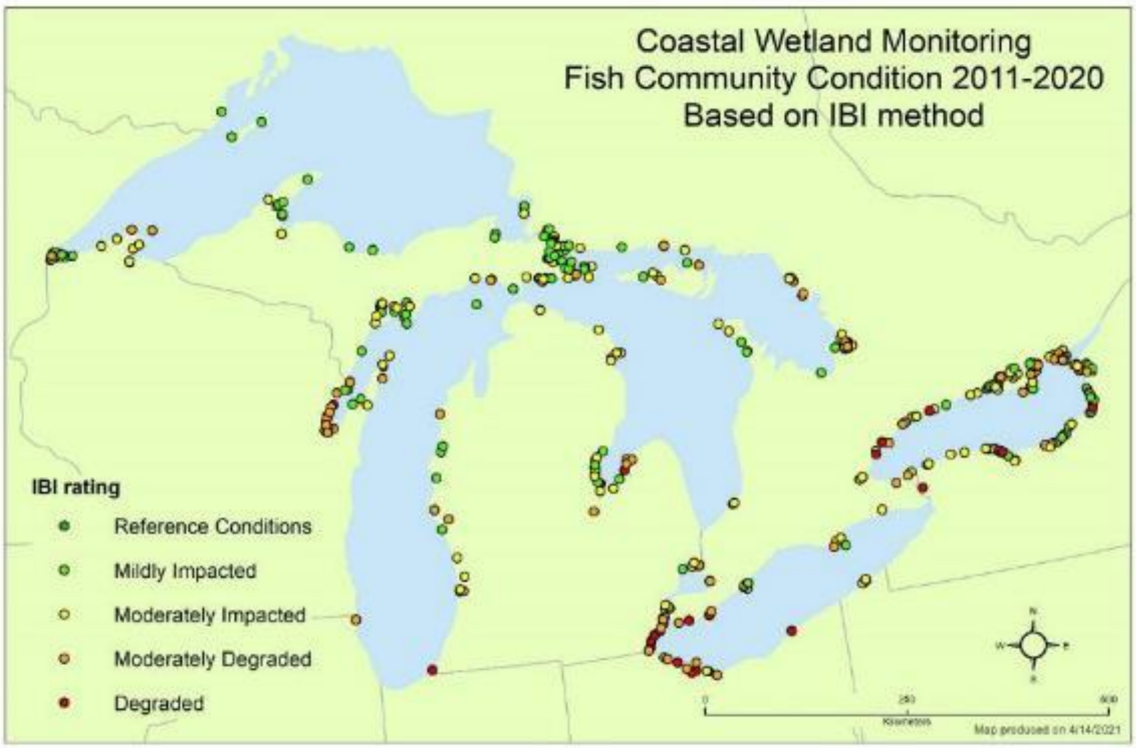

Figure 15. Condition of coastal wetland fish communties at sites with bulrush, cattail, lily, or submerged aquatic vegetation zones. Based primarily on data collected between 2016 through 2020 with 2011-2015 data used for sites that were only sampled in those years.

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.

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.

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*)

Despite our efforts to develop a basin-wide IEC estimate, 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.

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 15). 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.

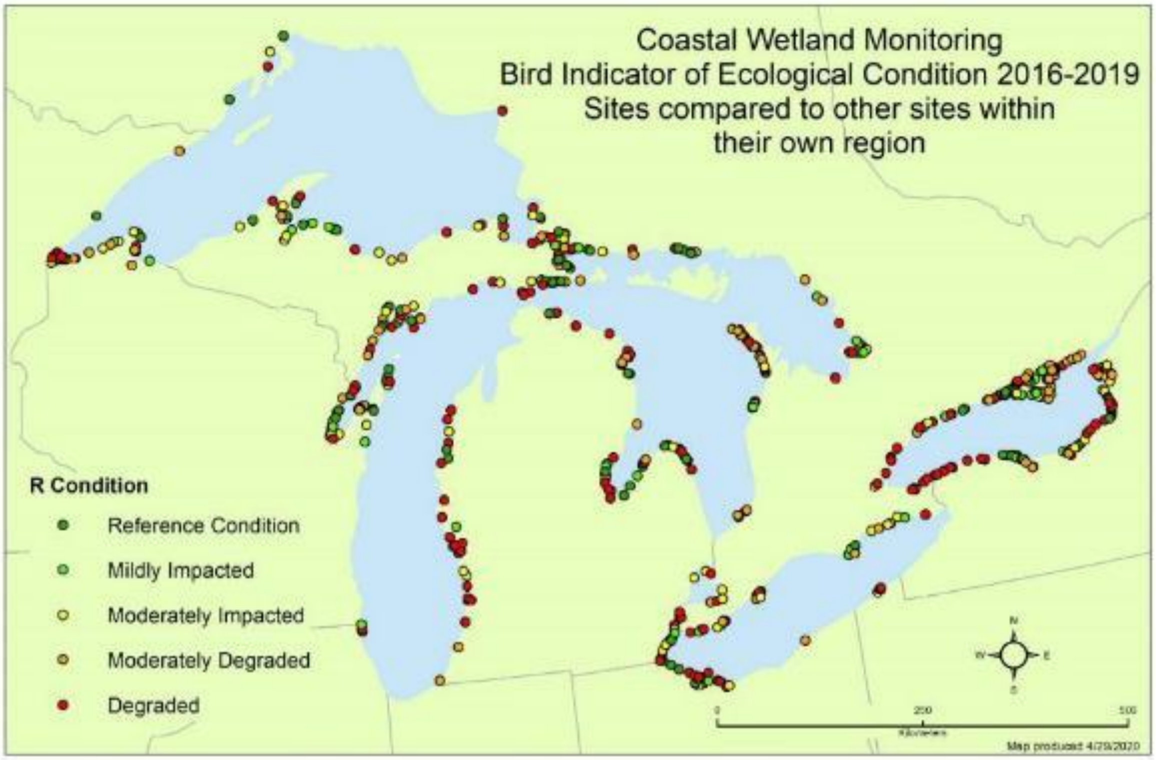

Figure 16. Condition of coastal wetland bird communties with wetlands compared regionally (see text for regions). This indicator is based on the IEC method using data collected primarily between 2016 and 2019.

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 highly significant difference among lakes (F test, $p < 0.001$) and a significant interaction between lake and year group ($p = 0.0016$). Year group (2011-2014 vs. 2015-2017) itself was not a statistically significant factor for anurans ($p = 0.20$).

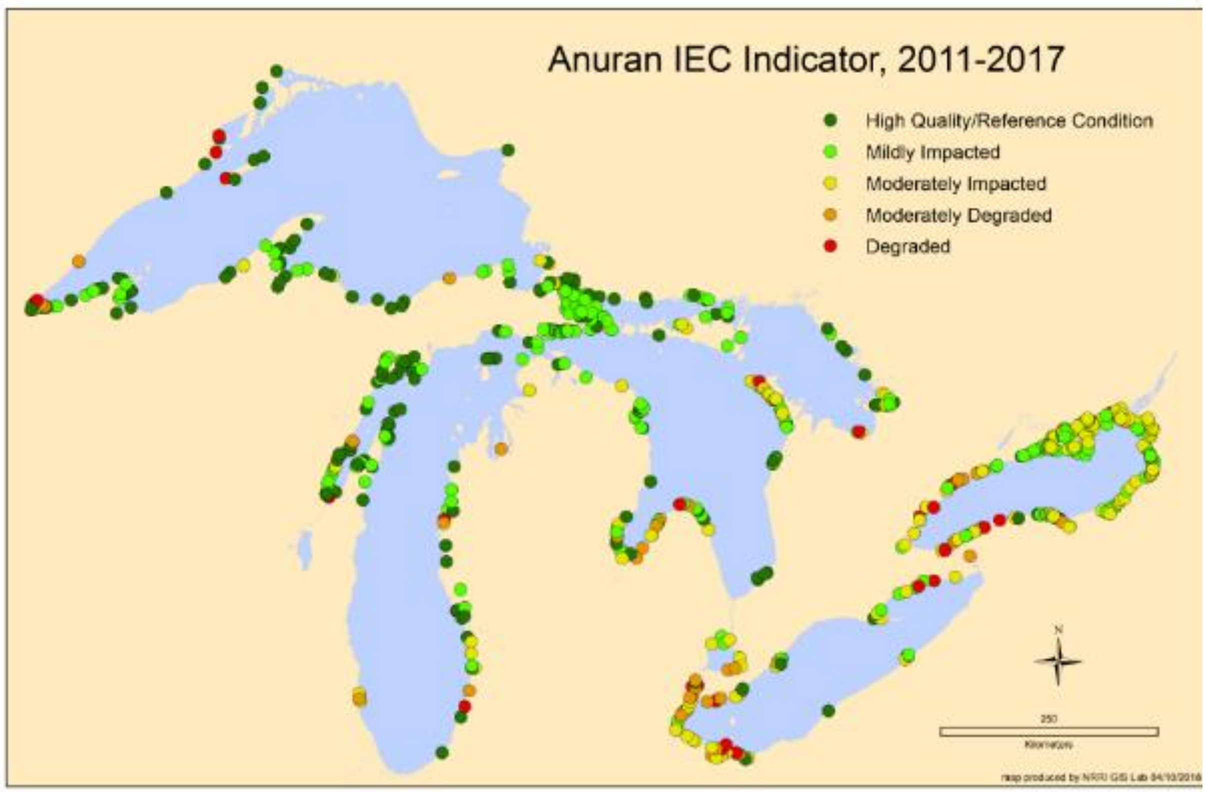

Figure 17. Condition of coastal wetland calling anuran communties. This indicator is based on the IEC method using data from 2011 through 2017.

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 2-4 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)

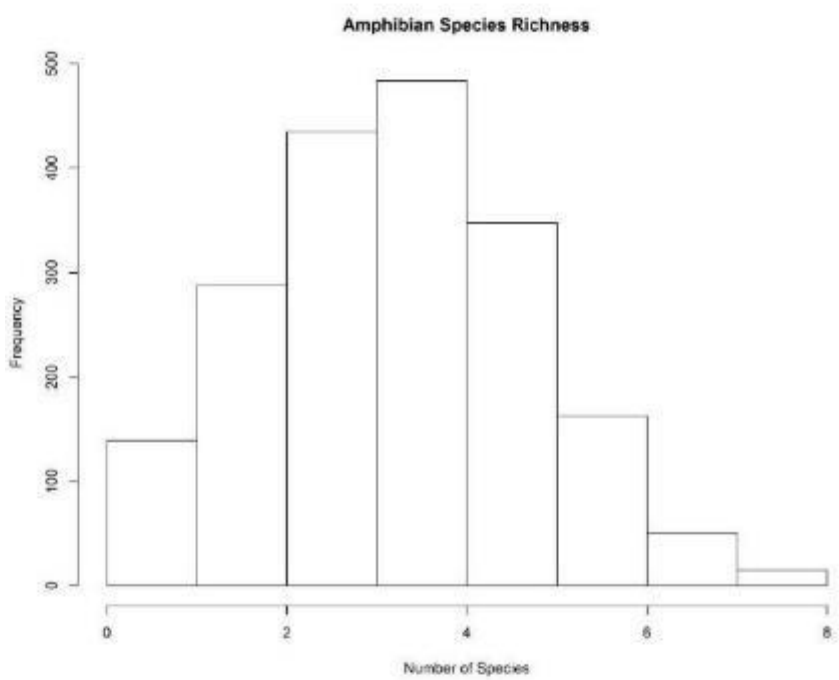

Figure 18. Distribution of species richness at coastal wetland sample points from 2011-2017. Number of species refers to the total number of species recorded during three visits to the point during a given year.

Finally, we have developed a disturbance gradient (SumRank) indicator (Harrison et al. 2019). This indicator is based on landscape stressor data, local stressor data seen at the site itself, and water quality data collected from each aquatic macrophyte plant morphotype (Figure 19).

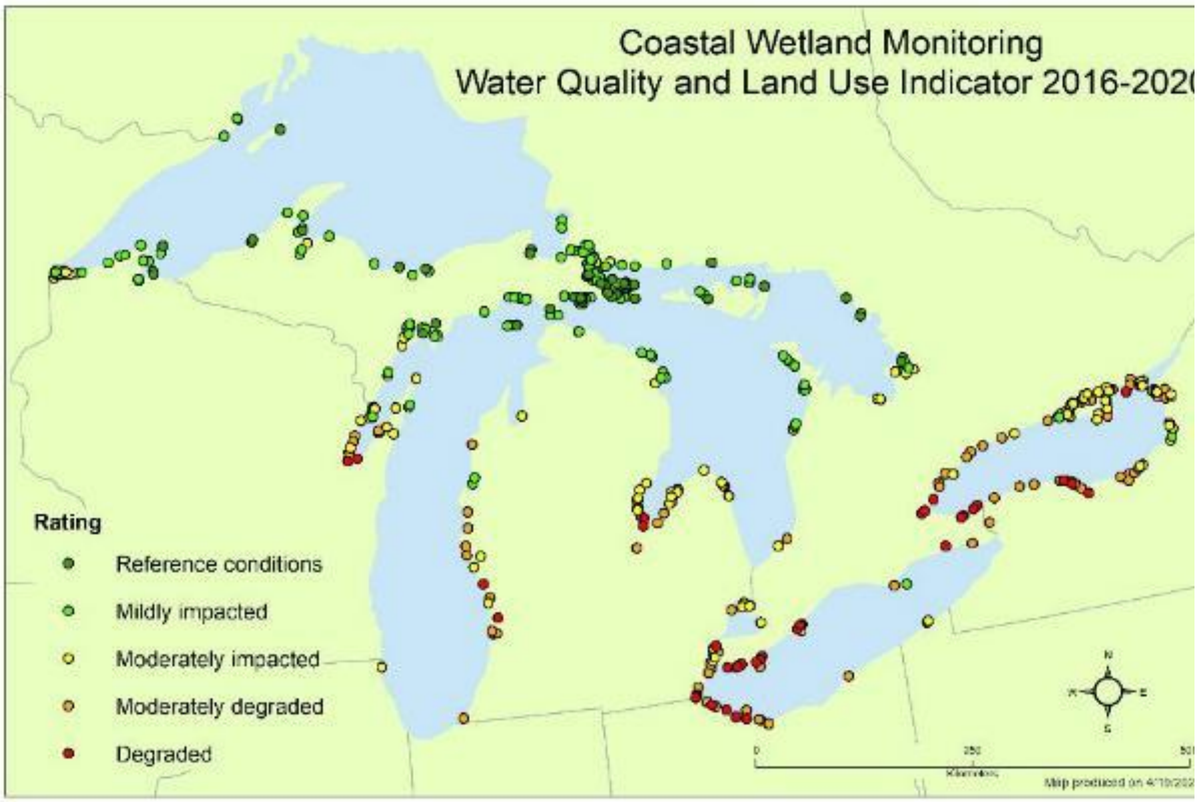

Figure 19. Disturbance gradient (SumRank) indicator. This indicator is based on landscape stressor data, site-based stressor data, and site water quality data. This is based primarily on data collected from 2016 through 2020.

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, including modifying and enhancing the site as required to meet CWMP and GLNPO 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 20), 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).

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."

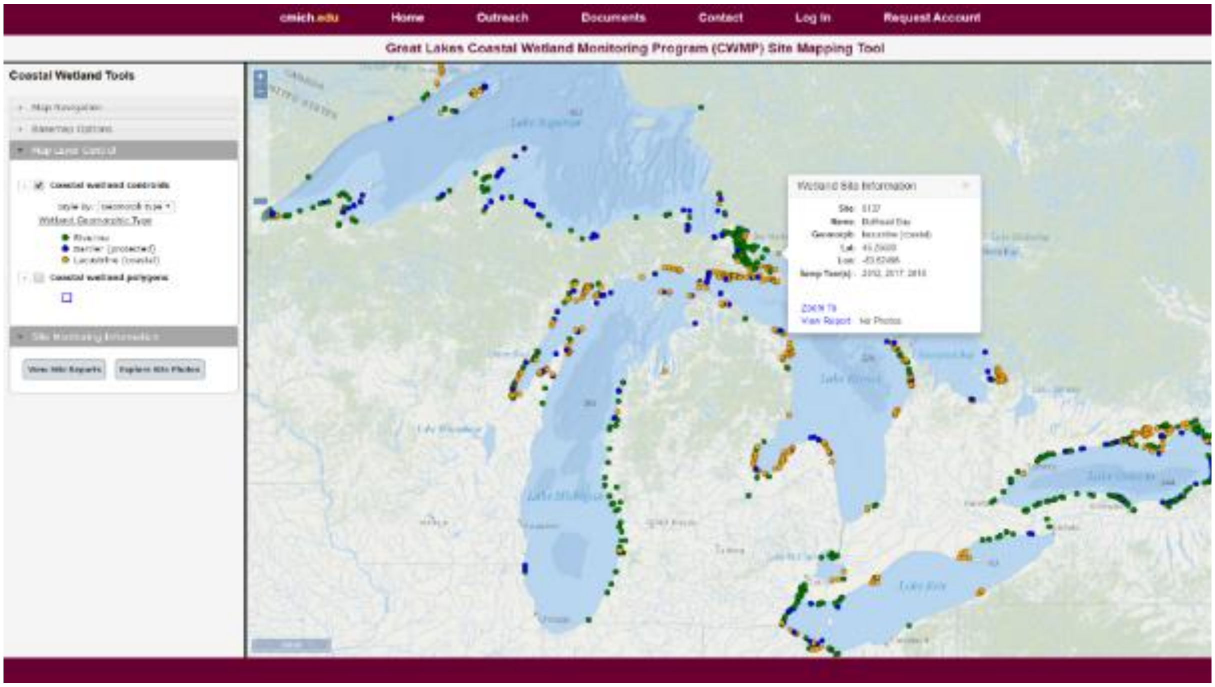

Figure 21. Coastal Wetland Mapping Tool – Public Version (geomorphic type view).

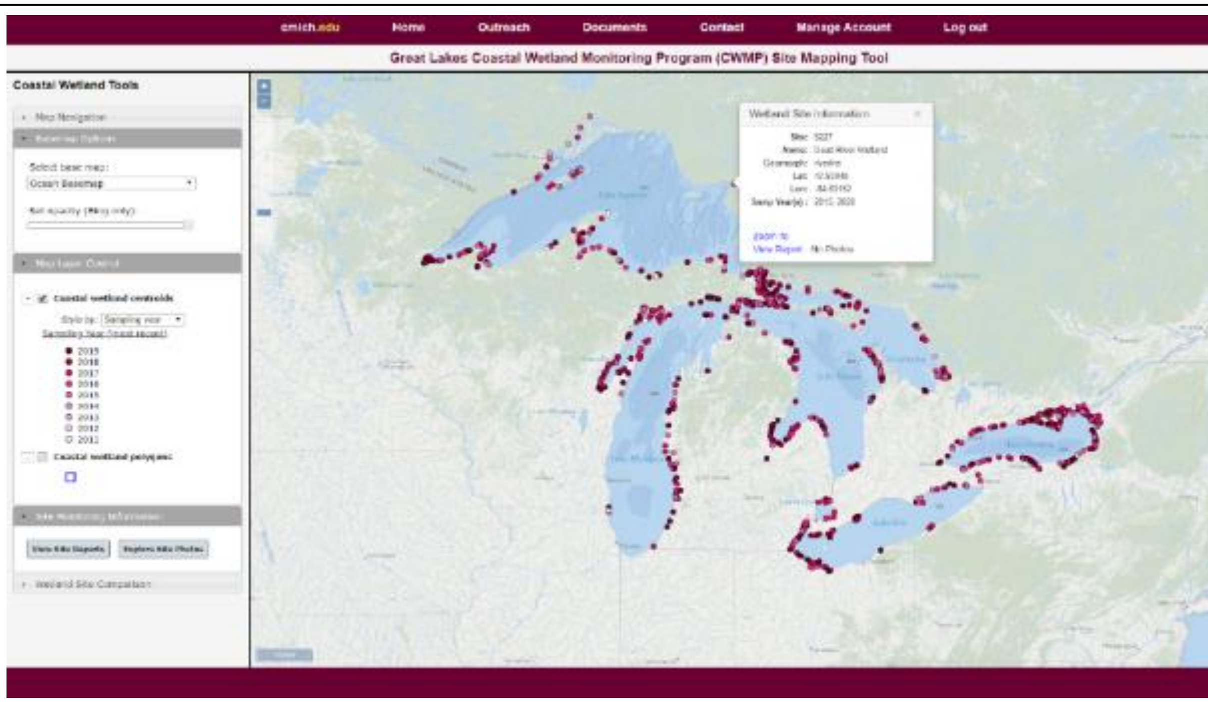

Figure 22. Coastal Wetland Mapping Tool – Public Version (sampling year view)

Wetland centroids can be symbolized based on IBI scores for a specific biological community, as well as based on geomorphic type and year sampled. For example, vegetation IBI scores calculated for individual sites can be displayed by selecting the “Vegetation IBI” option available in the “Style by:” pull-down menu (Figure 23). In addition, the actual IBI scores can be viewed by clicking on an individual wetland centroid.

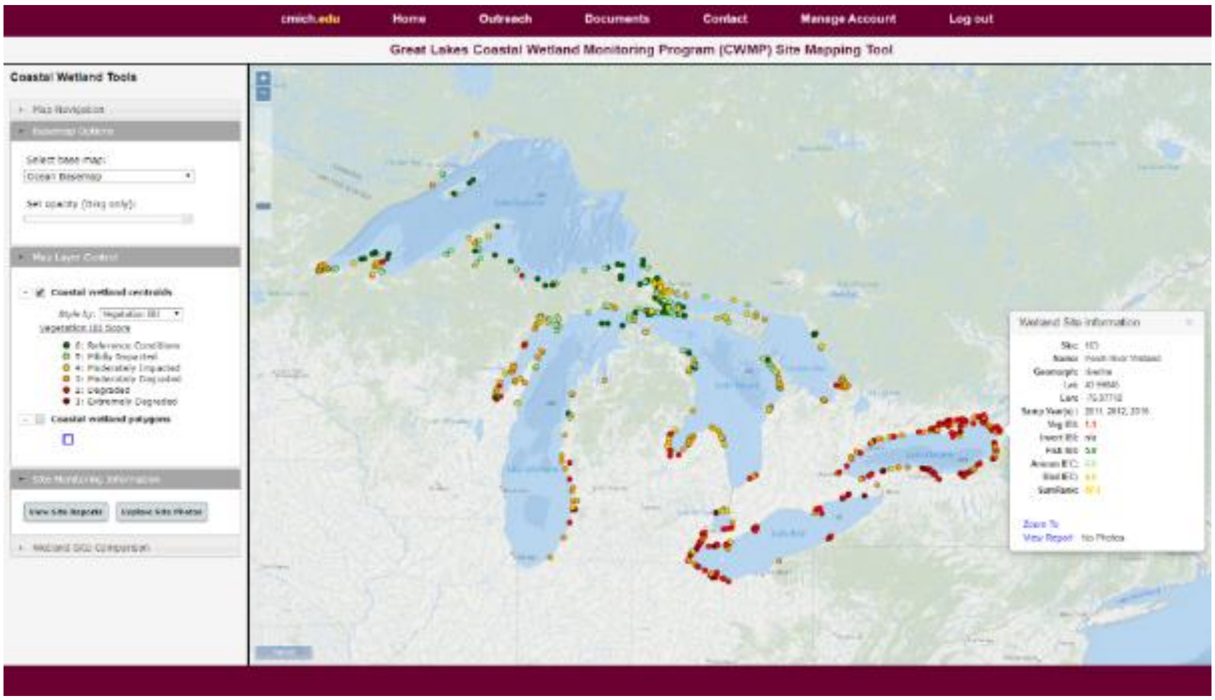

Figure 23. Coastal Wetland Mapping Tool with IBI scores displayed.

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

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

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

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

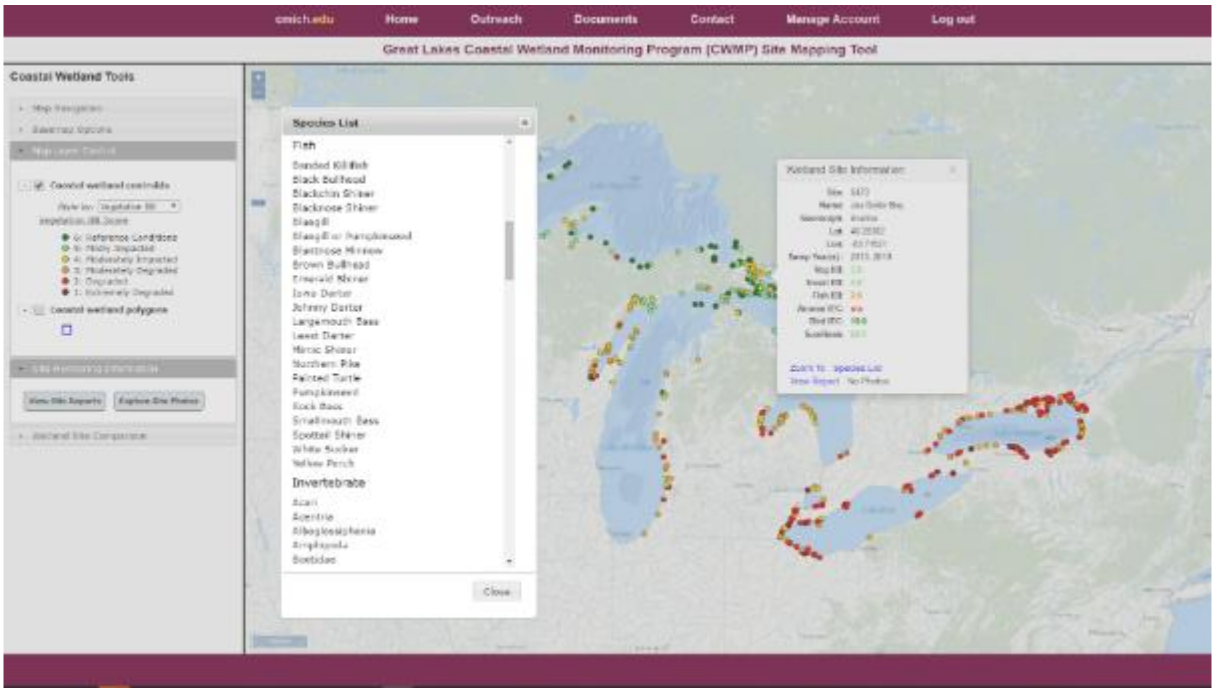

Figure 24. Coastal Wetland Mapping Tool with wetland macrophyte IBI scores and species list displayed.

Outreach to Managers

There have been many improvements to the website which assist external users with accessing and understanding the results, in particular the site reports and photos. Michigan EGLE is planning to host a new webinar in early 2022, with GLCWMP project PIs, to facilitate outreach and communication to target user groups throughout the Great Lakes basin, and to encourage use of the website in wetland management and restoration planning and monitoring. This will focus on updates to the website and tools like the site reports and photos, but will also cover basic database access levels and navigation as the site has been updated since the original webinar was recorded in 2017.

In 2021, EGLE hired a new Wetland Monitoring and Coastal Wetland Analyst to fill the vacancy left by Anne Garwood. In transitioning into the position, Katie Fairchild met with many of the partners of the GLCWMP. Training included virtual meetings, introduction to the website and Coastal Wetlands Decision Support Tool, and a 2-day GLCWMP field training hosted by CMU.

Katie will be leading the outreach efforts for EGLE going forward, including meeting planning, webinar scheduling and facilitation, and convening PIs and restoration partners to encourage application of the monitoring data in wetland restoration projects.

EGLE has also been encouraging restoration practitioners to use the GLCWMP data in project planning, goal setting, and development of adaptive management plans through Michigan's interagency Voluntary Wetland Restoration (VWR) Program. In the past year there have been a few VWR projects undergoing regulatory review by EGLE where we requested that the practitioners identify if/how the GLCWMP data were used in planning or design of the project, and whether or not the project would be monitored as a benchmark site. Although there is still some uncertainty in how practitioners can or should use these data in project planning, there is momentum in the VWR Program to increase awareness and application of these results.

In 2019, a one-hour documentary on the CLCWMP was release on PBS. The documentary aired across the U.S. "Linking Land and Lakes: Protecting the Great Lakes' Coastal Wetlands" chronicled the work of all 15 universities and government agencies documenting our scientists collecting data to help restore and protect these ecosystems. The WCMU production team traveled the entire Great Lakes basin over 18 months covering 5,000 miles in Michigan, Wisconsin, Indiana, Illinois, New York, Ohio, Pennsylvania, and Ontario, Canada. More than 40 coastal wetland scientists shared their expertise in the documentary. This 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 Basin Bird/Anuran Team at the Natural Resources Research Institute, University of Minnesota Duluth

Team Members

Dr. Annie Bracey (PI, team lead – Bird & Anuran Surveys) –permanent/year-round (returning)
Dr. Alexis Grinde (Avian Ecology Lab Director) – permanent/year-round (returning)
Josh Bednar (field tech – Anuran Surveys) – permanent/year-round (returning)
Nick Walton (field tech – Bird & Anuran Surveys) – permanent/year-round (returning)
Alexis Liljenquist (technician – Field gear coordinator) – temporary (returning)
Reid Siebers (technician – Data management coordinator) – temporary (new)
Kara Snow (technician – Data management coordinator) – graduate assistant (new)
Ryan Steiner (technician – Field coordinator for entire lab) – permanent (new)

Training

Due to work-related restrictions in travel associated with the COVID-19 pandemic, training for anuran surveys was held remotely on 14 April, 2021 and for bird surveys on 25 May, 2021. During the 2021 field season, three individuals conducted the anuran and bird surveys, all of whom had surveyed on this project in previous years, so there were no new employees to train. Training involved instructing individuals on how to conduct standardized field surveys, on basic travel procedures, and on appropriate field safety measures. Individuals were trained to proficiently complete field sheets. Rules for site verification, safety issues including caution regarding insects (e.g., Lyme's disease), GPS and compass use, boat safety, working near traffic or roadways, and record keeping were also included in field training to insure that the guidelines in the QAPP were being followed.

All individuals involved in conducting the surveys had previously taken and passed each of the following tests on 1) anuran calls, 2) bird vocalization, and 3) bird visual identification via an on-line testing system established at the University of Wisconsin, Green Bay – see http://www.birdercertification.org/GreatLakesCoastal. Training documents, including SOPs and QAQC measures , specifically related to sampling procedures are available on the program website – see https://www.greatlakeswetlands.org/Sampling-protocols.vbhtml. Training documents related to field safety were provided by NRRI and were reviewed with the PI at the time of training. Due to safety concerns associated with COVID-19, our team imposed thorough field safety measures which were approved by NRRI and the University of Minnesota prior to any personnel conducting field work. All employees were given extensive guidance on how to prevent the spread of COVID-19.

Challenges and Lessons Learned

The primary challenge for the NRRI bird/anuran team was related to logistics associated with accessing sites and imposed international travel restrictions. Our team typically surveys many of the wetland sites in northern Lake Huron and in and around Thunder Bay, which we were unable to do again this year due to travel restrictions to Canada. It was also more challenging to contact private homeowners to request access to wetlands via private property.

Site Visit List

In 2021, a total of 27 wetland sites, located in the U.S only, were initially selected to be surveyed for birds and anurans by the western basin bird and anuran team. Although all of these sites had been surveyed at least once during the 2011-2020 project period, by at least one taxonomic group, we still needed to determine accessibility and site conditions, which may have changed during this time period (e.g., changes in property ownership or water levels). A total of 4 sites were marked as 'could not access site' for anurans and for birds. The majority of these situations were associated with not being able to contact land ownership or due to travel safety issues. One site was listed as 'not sampling BM' for anurans due to safety concerns. Six sites were listed as visit rejects because habitat did not meet sampling criteria (e.g., sites were composed primarily of forested wetlands).

A total of 17 wetlands were sampled in 2021 by the western basin bird and anuran team, all of which were located along the south shore of Lake Superior in Minnesota, Wisconsin, and in the upper peninsula of Michigan. Of these 17 sites, one was designated a benchmark site (7076) located in the St. Louis River in the Duluth-Superior Harbor. Two sites were designated panel re-sample sites, one located south of Bayfield, WI near Port Superior Marina (1188) and the other located north of Baraga, MI on the Keweenaw Bay Indian Community lands (0974). The remaining 14 sites surveyed were regular panel-year sites. Anuran surveys began 17 April and bird surveys began 06 June, 2021. Anuran sampling was completed by 10 July and bird surveys were completed by 02 July.

Panel Survey Results

The data collected in 2021 by the western basin bird and anuran team is still being entered and QC'd, therefore, there are no summaries to report. We will provide summaries for taxa and any noteworthy observations in the 2022 spring semi-annual report.

Extra Sites and Data

Additional point-count locations were established in Allouez Bay (site 1077) in Superior, WI. Details for why additional data were collected at this site are provided in the 'Additional Funding and Projects' section. An additional six point-count locations were surveyed via boat to better survey sites within the wetland complex. We also deployed Automated Recording Units (ARUs) to supplement data collected by the 10-min in-person surveys. These data were externally funded and were not entered into the data management system. They are being stored digitally at NRRI.

Wetland Condition Observations and Results

The western basin bird and anuran team does not have any noteworthy observations to report regarding wetland condition of sites sampled in 2021.

Data Processing

All bird, anuran, and point-count level vegetation surveys have been electronically scanned and digitally stored as PDFs at NRRI. Data entry and QAQC will be completed by November 2021. All GPS coordinates associated with 2021 field sampling have been uploaded to the CWMP database. The physical data sheets from the point-count level vegetation surveys will be mailed to Doug Tozer at Bird Studies Canada for processing by November 2021.

Mid-season QC Check Findings

In-person mid-season QC checks were not conducted by the western basin bird and anuran team during the 2021 field season due to logistical constraints related to Covid-19. The individuals conducting the bird and anuran surveys have been doing field work since the inception of the program and therefore are extremely familiar with proper survey procedures and are highly skilled in species identification. In place of in-person checks, the surveyors reported to the PI daily during field work. Surveyors also took pictures of sites where habitat was suspected to be inappropriate. These photos were then sent to the PI to verify whether the sites in question met sampling criteria or not. Surveyors also described general field conditions and any issues associated with accessing sites. Data sheets were scanned and sent to the PI periodically throughout the field season to identify any potential issues with an individual's data collection methods. Surveyors were able to effectively communicate with the PI throughout the field season and therefore there were no QC issues that arose or needed to be addressed.

Audit and QC Report and Findings

The bird and anuran team leads spent a significant amount of time evaluating the logic statements that GDIT developed based on reading the bird and anuran QAPP and SOPs. Each statement was evaluated by our team for its ability to effectively QC the data collected. This process provided our team the opportunity to collectively discuss possible misinterpretations of the data, and to identify language in our QAPP and SOPs that needed clarification. Bird and anuran team leads collectively reviewed each query and determined which we thought were valid, which were not, and provided feedback on those that required modification, made suggestions as to how they should be modified and why. We also updated our SOPs to enhance readability, maintain consistency in language between bird and anuran SOPs, and to provide clarification where needed. We will continue to work with the CWMP leadership team to make any updates and modifications that will facilitate ease of use and interpretation of the bird and anuran data set.

Additional Funding and Projects

Allouez Bay Marsh Bird Restoration Project. 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), Superior, WI, which required a boat to access the interior of the wetland. This site 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. Restoration plans are currently being developed and will be implemented in the coming years.

This project is currently in Phase 1, which is a feasibility and design for restoration of marsh bird habitat. Other collaborators include individuals from Douglas County, City of Superior, Great Lakes Indian Fish and Wildlife Commission, St. Croix Environmental and Natural Resources Department, Fond du Lac Band of Lake Superior Chippewa, University of Wisconsin Superior, US Army Corps of Engineers, and Minnesota Land Trust. In Phase 2, we will identify metrics for assessing changes in marsh bird communities before and after restoration. The data collected at this site from the CWMP since 2011 will be essential in assessing pre-restoration bird community structure, for defining metrics, and for post-restoration assessment.

Other Collaboration Activities

National and Great Lakes Audubon. The bird and anuran team continue to keep regular communications with National and Great Lakes Audubon personnel regarding potential future collaborative efforts in using the CWMP bird data to describe bird community dynamics and the importance of Great Lakes coastal wetlands to marsh bird populations. There are several Audubon funded projects that are requesting use of CWMP data. Our team is in the process of drawing up agreements that will assure CWMP leads are involved at all levels to provide guidance on appropriate uses of these data and for inclusion in any resulting publications.

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 were developed 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 begin in the Spring of 2020 and was completed in Fall of 2021.

Update (Sept 2021): The data compiled for the Natural Areas Project continues to be of value for informing a larger St. Louis River Landscape Conservation Design, led by Minnesota Land Trust (https://dsmic.org/wp-content/uploads/2018/03/MN-Land-Trust-Landscape-Conservation-Design.pdf).

The Grassy Point restoration plans, guided by avian breeding and stopover habitat needs, are currently in progress. Physical creation of an island and restoration of a degraded plant community within the adjacent wetland have begun. Planting of native vegetation took place in

May-Aug 2021. A component of the post-restoration monitoring will include surveys of both breeding and migratory bird use.

Other Data Requests

No data requests have occurred since the previous semi-annual report.

Related Student Research

Currently no student research projects are associated with the bird and anuran group at NRRI.

Western Basin Fish, Invertebrate and Water Quality Team at the Natural Resources Research Institute, University of Minnesota Duluth

Team Members

The Western Basin Fish, Invertebrate and Water Quality Team consists of PI Dr. Valerie Brady, full-time NRRI staff and crew chiefs Josh Dumke, Robert Hell, Holly Wellard-Kelly, and Kari Hansen; returning summer field technician Sierra Kryzer, and new summer field technicians Lara Scott, David Baldus, and Nichole Angell.

Training

The NRRI fish/invert/wq team held virtual project training from June 6 – 11, 2021 (due to COVID-19), as well as hands-on training for new summer technicians during their first site visit in Green Bay, WI (date range June 13 – 25, 2021). The entire NRRI team (9 participants) were in attendance during training modules presented by permanent staff who have been working on the Coastal Wetland Monitoring Program for >5 years. Topics covered were: field safety from environmental hazards, safe boating practices, approved scientific collection permits and responsibilities of the field teams to give prior notification to local fisheries managers and conservation officers before collecting fish from a wetland, Coastal Wetland Monitoring Program overview and introduction to Standard Operating Procedures and datasheets, GPS use and annual QC check, uploading GPS files to the program website, fish collection methods and identification, proper euthanasia and preservation methods for retained fish, water quality data and sample collection, post-collection processing of water samples (filtration and titration), daily calibration of water quality multiparameter instruments, invertebrate collection and field picking of samples, vegetation identification and habitat quadrats. Safety training was also done virtually. The hands-on training was led by experienced crew chiefs Kari Hansen, Bob Hell, and Holly Wellard-Kelly who have all worked on CWMP for more than 5 years. During hands-on training the experienced NRRI crew chiefs (n=3) guided new summer technicians (n=3) and returning summer technicians (n=1) on fish identification (with real fish rather than pictures), how to determine vegetation zones, vegetation identification, setting and pulling fyke nets, and which invertebrates to pick from trays (e.g. don't pick terrestrial insects, spiders, or large zooplankton).

Challenges and Lessons Learned

The 2021 field season saw some return of normal operations as COVID-19 vaccinations became available and travel restrictions loosened compared to our 2020 field season. However, we still dealt with challenges finding and selecting housing options for our traveling field teams to reduce their exposure to crowds and limit time spent in regions with high COVID-19 infection rates. The NRRI team completed their assigned field sampling without COVID-19 infection.

Site Visit List

943 (Powell Point): regular panel site; could not sample due to drought conditions making this a dry meadow rather than a wet meadow. There was not enough water anywhere to even sample water quality or d-nets for invertebrates.
969 (Huron River): regular panel site; sampled fish, inverts, and water quality.
972 (Pequaming): regular panel site; sampled inverts and water quality.
974 (Sand Point): regular panel re-sample site; sampled inverts and water quality.
976 (Portage River #1): regular panel site; sampled fish, inverts, and water quality.
979 (Silver Creek): regular panel site; sampled fish, inverts, and water quality.
1076 (Poplar River): regular panel site; sampled fish, inverts, and water quality
1096 (Pokegama River): regular panel pre-sample site; sampled fish, inverts, and water quality.
1152 (Dead River): regular panel site; sampled fish, inverts, and water quality
1188 (Pikes Creek): regular panel re-sample site; sampled inverts and water quality.
1441 (Point au Sable): regular panel pre-sample site; sampled fish, inverts, and water quality. This site is often sampled as a benchmark site because of restoration activities taking place there.
1449 (Peters Marsh): panel re-sample site; sampled inverts and water quality.
1456 (Long Tail Point #1): regular panel pre-sample site; sampled fish, inverts, and water quality.
1458 (Dead Horse Bay #9): regular panel site; sampled fish, inverts, and water quality.
1459 (Little Tail Point #1): panel re-sample site; sampled fish, inverts, and water quality.
1469 (Peshtigo River #1): regular panel site; sampled fish, inverts, and water quality.
1497 (Whitefish River #3): regular panel site; sampled fish, inverts, and water quality.
1519 (Garden Bay): regular panel site; sampled fish, inverts, and water quality.
1697 (Saumico River Area): BENCHMARK; sampled fish, inverts, and water quality. Designated as a benchmark site because The Nature Conservancy is conducting restoration work here, in part to encourage spawning by Northern Pike.
1698 (Little Saumico River Area): regular panel site; sampled fish, inverts, and water quality.
1720 (Little Bay de Noc): regular panel re-sample site; sampled fish, inverts, and water quality.
1732 (Wisley Bay Area): regular panel site; could not sample due to no safe access. The nearest boat launch is over 12 miles away, and the nearest carry-in launch point for small boats (from

public property) is over 3 miles away. The shoreline is all residential property here and in the past when field teams tried talking to residents to access the wetland from private property, they were not greeted with friendly invitations.
1745 (Ogontz Bay Area): regular panel pre-sample site; sampled inverts and water quality.
7033 (Oconto Marsh #2): regular panel site; sampled fish, inverts, and water quality.
7049 (21st Ave W): BENCHMARK; sampled inverts and water quality. Designated as a benchmark site because the area is targeted for restoration to become a coastal wetland once again. Thus far, restoration efforts have been relatively unsuccessful as vegetation will not re-establish. Note that this site currently does not meet the criteria for a coastal wetland because it contains almost no aquatic vegetation.
7076 (Perch Lake): BENCHMARK; sampled fish, inverts, and water quality. Designated as a benchmark site to get pre-restoration data before the site receives a bigger connection to the St. Louis River in 2022 (currently the connection is a culvert). Although this site qualifies as a coastal wetland, it is far enough up-river in the St. Louis River Estuary that it was not on the original coastal wetland site list.

Panel Survey Results

Regular Panel Sites:
943 – First sampled on 7/18/2011. Last visited on 7/18/2021 and crew leader Kari Hansen determined the site was too dry to meet sample criteria. Site 943 was not sampled in 2021.

969 – First sampled on 7/19/2011. Last visited on 7/12/2021 and sampled an SAV zone for fish, inverts, and water quality, as well as an Outer Schoenoplectus zone for inverts and water quality. The NRRI team accessed the site using inflatable Zodiak boats (Fig 25). Nets at this site (n=3) captured 5 painted turtles and 3 native crayfish. No invasive species were detected at this site. Fish species present at the site were Brown Bullhead, Golden Shiner, Rock Bass, Pumpkinseed, White Sucker, Blacknose Shiner, Yellow Perch, Iowa Darter, and Common Shiner. Iowa Darter are a native and colorful benthic fish not frequently encountered by the NRRI team (Fig 26).

Figure 25. NRRI fish/invert/wq crew chief Bob Hell and summer technician Nicole Angell get ready to sample site 969.

972 – First sampled on 7/15/2016. Last visited on 7/13/2021 and sampled a Mixed Emergent zone for inverts and water quality. This site was accessed on foot with permission from the Keweenaw Bay Indian Community (KBIC). Crew chief Bob Hell noted water in the wetland was barely connected to the lake by a culvert, but the wetland would likely be connected periodically during rain events.

Figure 26. Iowa Darter captured in an SAV zone of site 969.

974 (re-sample) – First sampled on 7/29/2015. Last visited on 7/14/2021 and sampled SAV and Lily zones for inverts and water quality. This site was accessed using inflatable Zodiaks with permission from the Keweenaw Bay Indian Community (KBIC). Crew chief Bob Hell noted KBIC requested the team not set fyke nets to avoid disturbing the newly-seeded wild rice.

976 – First sampled on 7/22/2011. Last visited on 7/15/2021 and sampled an Outer Schoenoplectus zone for fish, inverts, and water quality. Nets at this site (n=3) captured 1 common snapping turtle, 3 native crayfish, and 6 invasive Rainbow Smelt. Fish species present at the site were Central Mudminnow, Johnny Darter, Rock Bass, Pumpkinseed, White Sucker, Blacknose Shiner, Spottail Shiner, Yellow Perch, Troutperch, Rainbow Smelt, and Smallmouth Bass.

979 – First sampled on 7/21/2011. Last visited on 7/19/2021 and sampled an SAV zone for fish, inverts, and water quality, as well as Wet Meadow, Arrowhead, and Typha zones for inverts and water quality. This was a large site with four distinct vegetation zones, but most could not be fished because the vegetation was growing on unstable floating bog mats. Nets at this site (n=3) captured 1 common snapping turtle, 6 painted turtles. No crayfish bycatch or invasive fish species were detected at this site. Fish species present at the site were Northern Pike, Pumpkinseed, Golden Shiner, Rock Bass, Spottail Shiner, Brown Bullhead, Yellow Perch, Smallmouth Bass, and Johnny Darter.

1076 – First sampled on 9/20/2011. Last visited on 8/3/2021 and sampled an SAV zone for fish, inverts, and water quality, as well as a Lily zone for inverts and water quality. Nets at this site (n=3) captured 1 common snapping turtle, 1 painted turtle, 5 native crayfish, and invasive fish Tubenose Goby (n=1) and White Bass (n=1). Fish species present at the site were Black Bullhead, Golden Shiner, Tadpole Madtom, Common Shiner, Black Crappie, White Bass, Blacknose Shiner, White Sucker, Pumpkinseed, Yellow Perch, Rock Bass, and Tubenose Goby.

1152– First sampled on 7/17/2011. Last visited on 7/17/2021 and sampled Lily and Typha zones for fish, inverts, and water quality. Nets at this site (n=6) captured 4 painted turtles, and 4 native crayfish. No invasive fish species were detected at this site. Fish species present at the site were Yellow Perch, Rock Bass, White Sucker, Northern Pike, Spottail Shiner, Brown Bullhead, Smallmouth Bass, Largemouth Bass, and Black Bullhead.

1188 (re-sample) – First sampled on 7/31/2015. Last visited on 8/2/2021 and sampled an SAV zone for inverts and water quality. Crew chief Kari Hansen noted that air quality was poor while sampling this wetland, which was a phenomenon experienced by Western Lake Superior during Canadian wildfires this summer.

1449 (re-sample) – First sampled on 6/25/2015. Last visited on 6/16/2021 and sampled an SAV zone for fish, inverts and water quality, as well as a Typha zone for inverts and water quality. Nets at this site (n=3) captured 1 common snapping turtle, 6 painted turtles, and invasive

Common Carp (n=8) and Round Goby (n=1). No crayfish bycatch were captured at this site. Fish species present at the site were Common Carp, Bowfin, Brown Bullhead, Yellow Perch, Bluegill, Golden Shiner, Pumpkinseed, Emerald Shiner, Green Sunfish, Blacknose Shiner, Largemouth Bass, Round Goby, Banded Killifish, Longnose Gar, Longnose x Shortnose Gar hybrid, and Black Bullhead. At this site both Longnose Gar and Longnose x Shortnose Gar hybrid were captured in fyke nets. Longnose x Shortnose Gar hybrids have only been found in wetlands of the Green Bay, WI area of Lake Michigan, but they are abundant in this region and it is actually less common to capture a Longnose Gar. Crew chief Kari Hansen noted that invasive *Phragmites* was present at the site, but due to low water levels, it was all dry and did not meet CWM sample criteria.

1458 – First sampled on 6/29/2011. Last visited on 6/17/2021 and sampled SAV and Typha zones for fish, inverts, and water quality. Nets at this site (n=6) captured 1 common snapping turtle, 7 painted turtles, and invasive Common Carp (n=40). No crayfish bycatch were captured at this site. Fish species present at the site were Bowfin, Pumpkinseed, Yellow Perch, Brown Bullhead, Green Sunfish, Common Carp, Longnose x Shortnose Gar hybrid, Bluegill, Banded Killifish, Central Mudminnow, and Largemouth Bass.

1459 (re-sample) – First sampled on 6/26/2015. Last visited on 7/23/2021 and sampled an SAV zone for fish, inverts, and water quality, as well as a Typha zone for inverts and water quality. Nets at this site (n=3) captured 8 painted turtles, and invasive Common Carp (n=6). No crayfish bycatch were captured at this site. Fish species present at the site were Bowfin, Green Sunfish, Yellow Perch, Banded Killifish, Bluegill, Black Crappie, Pumpkinseed, Common Shiner, Largemouth Bass, Black Bullhead, Brown Bullhead, and Common Carp.

1469 – First sampled on 7/1/2011. Last visited on 7/21/2021 and sampled SAV and Typha zones for fish, inverts, and water quality. Nets at this site (n=6) captured invasive Common Carp (n=6). No crayfish or turtle bycatch were captured at this site. Fish species present at the site were Central Mudminnow, Common Carp, Pumpkinseed, Golden Shiner, Brown Bullhead, Bowfin, and Rock Bass. Crew chief Kari Hansen noted that wild rice was present at the site, but it was known to be recently seeded so the crew did not disturb it (per PI Valerie Brady approval). The NRRI field team also saw another field team from University of Wisconsin – Green Bay who were cutting invasive *phragmites* at the site.

1497 – First sampled on 8/2/2011. Last visited on 6/30/2021 and sampled SAV and Typha zones for fish, inverts, and water quality. Nets at this site (n=6) captured 7 common snapping turtle, 10 painted turtles, 6 native crayfish, and invasive fish Common Carp (n=4) and White Bass (n=1). Fish species present at the site were Northern Pike, Black Crappie, Pumpkinseed, Largemouth Bass, Yellow Perch, Smallmouth Bass, Logperch, Common Carp, Brown Bullhead, Bowfin, Central Mudminnow, White Bass, Golden Shiner, White Sucker, Bluegill, Walleye, and Longnose Gar.

1519 – First sampled on 7/15/2011. Last visited on 6/28/2021 and sampled Outer Shoenoplectus and Typha zones for fish, inverts, and water quality, as well as a *Phragmites* zone for inverts and water quality. Nets at this site (n=5; 1 did not fish) captured invasive Round Goby (n=59). No crayfish or turtle bycatch were captured at this site. Fish species present at the site were Rock Bass, Pumpkinseed, White Sucker, Round Goby, Blackchin Shiner, Bowfin, Brown Bullhead, Blacknose Shiner, Banded Killifish, Common Shiner, Yellow Perch, Bluntnose Minnow, Smallmouth Bass, and Emerald Shiner. Crew chief Kari Hansen noted that while this site is listed as riverine, the portion of wetland surrounding the river channel does not meet CWM criteria to sample. Thus, it was sampled as a lacustrine site.

1698 – First sampled on 6/30/2011. Last visited on 7/22/2021 and sampled Outer Shoenoplectus and SAV zones for fish, inverts, and water quality, as well as a Typha zone for inverts and water quality. Nets at this site (n=5; 1 did not fish) captured 3 common snapping turtles, and invasive fish Round Goby (n=2), Common Carp (n=5), White Perch (n=54), Gizzard Shad (n=1), and Alewife (n=3). No crayfish bycatch were captured at this site. Fish species present at the site were Bowfin, Bluegill, Central Mudminnow, Pumpkinseed, Green Sunfish, Banded Killifish, Yellow Perch, Brown Bullhead, Common Shiner, Black Crappie, Common Carp, Largemouth Bass, Longnose x Shortnose Gar hybrid, Alewife, Spottail Shiner, Round Goby, Yellow Bullhead, Rock Bass, White Perch, and Gizzard Shad.

1720 (re-sample) – First sampled on 7/16/2015. Last visited on 7/22/2021 and sampled Typha and SAV zones for fish, inverts, and water quality. Nets at this site (n=6) captured 4 painted turtles and 2 native crayfish as bycatch. No invasive fish were detected at this site. Fish species present at the site were Bluegill, Rock Bass, Pumpkinseed, Yellow Perch, Largemouth Bass, Brown Bullhead, Northern Pike, Black Crappie, Blackchin Shiner, Golden Shiner, Emerald Shiner, Central Mudminnow, Smallmouth Bass, and Bluntnose Minnow.

1732 – This site has never been sampled for fish/inverts/wq. It first came up in the sample rotation in 2011, but there was determined there was no safe public access point for the fish/invert/wq field team, and the property owners in this area were openly hostile toward the UW-Green Bay bird/anuran field team who visited this site earlier in the season. This site was not sampled by the fish/invert/wq crew in 2021 because public access options have not improved.

7033 – First sampled on 7/5/2011. Last visited on 6/23/2021 and sampled an Outer Schoenoplectus zone for fish, inverts, and water quality. Nets at this site (n=3) captured invasive fish Round Goby (n=41) and Alewife (n=2). No turtle or crayfish bycatch were captured at this site. Fish species present at the site were Alewife, Spotfin Shiner, Round Goby, Yellow Perch, Emerald Shiner, White Sucker, Brown Bullhead, Common Shiner, Spottail Shiner, Smallmouth Bass, Rock Bass, Northern Pike, and Bluntnose Minnow.

1096 – First sampled on 8/23/2011. Last visited on 8/16/2021 and sampled a Lily zone for fish, inverts, and water quality, as well as an SAV zone for inverts and water quality. Nets at this site (n=3) captured 2 painted turtles. No crayfish bycatch or invasive fish species were detected at this site. Fish species present at the site were Walleye, Black Crappie, Golden Shiner, Bluegill, Pumpkinseed, Brown Bullhead, Tadpole Madtom, Yellow Perch, Johnny Darter, and Northern Pike. Crew chief Kari Hansen noted that wild rice was present at this site, but it did not meet sample criteria.

1441 – First sampled on 7/1/2014. Last visited on 6/14/2021 and sampled an SAV zone for fish, inverts, and water quality, as well as a Typha zone for inverts and water quality. Nets at this site (n=3) captured 9 painted turtles, 1 northern map turtle (Fig 27), and lots of young-of-year (YOY) invasive Common Carp (n=2,061). No crayfish bycatch were captured at this site. Fish species present at the site were Longnose x Shortnose Gar hybrid, Bowfin, Central Mudminnow, Common Carp, Yellow Perch, Pumpkinseed, Green Sunfish, Bluegill, and Golden Shiner. Crew chief Kari Hansen noted that invasive *Phragmites* was present, but it was on dry land and did not meet criteria to sample. Map turtles are not threatened or endangered in Wisconsin, but it is rare for the NRRI fish/invert/wq team to encounter them as bycatch. This site has also been designated as a benchmark from 2013 through 2020 because of restoration activities being undertaken by University of Wisconsin – Green Bay, which manages the site. The NRRI crew accessed the site using inflatable Zodiaks, with permission from UWGB.

Figure 27. Northern map turtle captured in an SAV zone at site 1441.

1456 – This site has never been sampled for fish/inverts/wq. It was last visited on 6/22/2021 and sampled Typha and SAV zones for fish, inverts, and water quality. Nets at this site (n=6) captured 2 painted turtles, and invasive fish Quillback (n=2), Common Carp (n=3), and Round Goby (n=23). No crayfish bycatch were detected at this site. Fish species present at the site were Yellow Perch, Banded Killifish, Brown Bullhead, Quillback, Common Carp, Freshwater Drum, Pumpkinseed, Round Goby, Largemouth Bass, Spottail Shiner, Bluegill, Northern Pike, Channel Catfish, Longnose x Shortnose Gar hybrid, Emerald Shiner, and Rock Bass.

1745 – First sampled on 7/21/2012. Last visited on 6/29/2021 and sampled a Typha zone for inverts and water quality. Crew chief Kari Hansen noted that this site was mostly a sand beach, but there was enough cattail present for inverts and water quality sampling.

<u>Benchmark Sites:</u>

1697 – First sampled on 6/28/2011. Last visited on 6/21/2021 and sampled SAV and Typha zones for fish, inverts, and water quality. The SAV replicates were in the "pike fingers" created outside a diked portion of the site several years ago to enhance spawning by Northern Pike by creating shallow areas full of submergent vegetation. Nets at this site (n=6) captured 19 painted turtles, and invasive Common Carp (n=194). No crayfish bycatch were captured at this site. Fish species present at the site were Longnose x Shortnose Gar hybrid, Bowfin, Yellow Perch, Pumpkinseed, Bluegill, Yellow Bullhead, Brown Bullhead, Rock Bass, Largemouth Bass, Black Bullhead, Green Sunfish, Common Carp, Banded Killifish, and Central Mudminnow.

7049 – First sampled on 8/25/2011. Last visited on 8/12/2021 and sampled an Open Water zone for fish, inverts, and water quality. There was no vegetation at this site, and there hasn't been since our first visit in 2011, despite restoration efforts in recent years. Nets at this site (n=3) captured 6 invasive rusty crayfish, and invasive fish Tubenose Goby (n=101) and White Perch (n=1). No turtles were captured as bycatch. Fish species present at the site were Silver Redhorse, Black Crappie, Shorthead Redhorse, Tubenose Goby, Rock Bass, Pumpkinseed, Yellow Perch, Logperch, White Perch, Tadpole Madtom, and Johnny Darter.

7076 – This site has never been sampled for fish/inverts/wq. It was last visited on 8/9/2021 and sampled a Lily zone for fish, inverts, and water quality (Fig 28), as well as an SAV zone for inverts and water quality. Crew leaders noted that seiche was evident moving through the culvert which separates Perch Lake from the St. Louis River, as they watched water flowing in both directions (e.g. "in" and "out" of site 7076). This site was sampled to collect pre-restoration data before the culvert is removed in 2022 and a larger connection is made to the St. Louis River Estuary. The site is far enough upriver that it was not on the original GLCWMP site list even though it receives seiche effects. Nets at this site (n=3) captured 18 painted turtles. No crayfish were captured as bycatch, and no invasive fish species were detected. Fish species present at the site were Northern Pike, Pumpkinseed, Black Crappie, Bluegill, Largemouth Bass, and Brown Bullhead.

Figure 28. Crew leader Bob Hell collects invertebrates around a large fyke net set in a lily zone at site 7076.

Extra Sites and Data

No other sites or extra data collection were requested for 2021.

Wetland Condition Observations and Results

Water levels were lower in 2021 than they have been in quite a while. One site, 943, could not be sampled because the whole site was a dry meadow. Other site notes indicated *Phragmites* and even some cattail present at sites, but not submerged in water, so the vegetation did not meet sample criteria. The field team noted that very large Common Carp adults were often observed at sites, especially in wetlands connected to Lake Michigan. However, adult Common Carp do not seem to end up in our fyke nets in equal proportion to the numbers our team observes. Adult Common Carp are likely under-represented in our dataset.

Data Processing

As of October, 2021 the NRRI fish/invert/wq team has all 2021 invertebrate samples (n=142) in storage and will start processing them in the next few weeks.

Mid-season QC Check Findings

Primary crew leader Kari Hansen administered mid-season QC check of fish identification with new crew members. In 2021 the NRRI fish/invert/wq team surveyed sites as one 3-person crew.

New crew members were always working directly with experienced crew leaders, so the training and evaluation of new crew members was continuous. No issues were noted.

Audit and QC Report and Findings

None.

Additional Funding and Projects

None.

Other Collaboration Activities

PI Brady is collaborating with MPCA, MNDNR and WDNR on restoration planning and evaluation for sites in the St. Louis River Estuary. CWMP data and observations are provided as requested by the planning team.

Other Data Requests

Bobbie Webster from the University of Wisconsin Green Bay Cofrin Center for Biodiversity asked for a report of 2021 findings from site 1441 (Point au Sable), which UW-Green Bay manages.

Erin Johnson from The Keeweenaw Bay Indian Community (KBIC) asked for a report of findings from KBIC managed wetlands that NRRI surveyed in 2021. Sites of interest include 972 (Pequaming Wetland) and 974 (Sand Point Wetland).

Related Student Research

PI Brady's graduate student, Adam Frankiewicz, is working on an updated key to the sphaeriid (fingernail) clams of the Great Lakes region. He has used CWMP samples to help with this effort and CWMP field crews have collected clams for him.

Western Basin Vegetation Team at the Lake Superior Research Institute, University of Wisconsin Superior

Team Members

UWS vegetation team (4 members): Dr. Nick Danz (PI), Dr. Jeremy Hartsock (crew chief), Kelly Beaster (botanist), and Reed Schwarting (botanist)
Sub-contractor (1 individual): Ryne Rutherford (botanist)

Training

Except for Jeremy Hartsock (hired Jan 7, 2021), all other UWS team members have over 5-years prior experience working on the project, are qualified to train others, and therefore do not require the standard trainings given to new hires. Jeremy Hartsock received multiple trainings that are listed below in detail. Further, during all in-field vegetation surveys, crew chief Jeremy Hartsock was accompanied by at least one UWS team member listed above to ensure protocols were followed correctly, and to assist identifying vegetation to the species level.

- June 9 – 11, 2021 on Zoom: Jeremy Hartsock received “Field Crew Orientation” training organized by Val Brady’s NRRI team. Topics included CWM project overview, fish ID, and water quality sampling.
- September 17th, 2021 on Zoom: Jeremy Hartsock received “CWM Site Selection System” training organized by Val Brady to ensure data was entered correctly into the database.

Challenges and Lessons Learned

Similar to 2020, COVID-19 precautions were followed to the best of our abilities. All UWS team members were fully vaccinated prior to the start of field season, which made working together safer overall as compared to the 2020 season. Face masks were worn by all team members while riding in vehicles and during interactions with the public.

In comparison to years 2018 – 2020, sampling across western basin sites in 2021 was less challenging due to lower water levels, namely for Lake Michigan sites. That said, water levels were still high in some areas, making some sites challenging to navigate (Figure 29).

Site Visit List

Regular panel sites (15 total): 1469, 943, 7033, 969, 1458, 979, 1519, 1152, 1698, 972, 976, 1076, 1697, 1497, and 1732 (all sites sampled)
Resample sites (5 total): 1720, 1188, 974, 1449, and 1459 (all sites sampled)
Presample sites (4 total): 1096, 1745, 1441, and 1456 (all sites sampled)
Benchmark sites (2 total): 7049 (did not sample), and 7076 (sampled). Post restoration assessment of site 7049 (21st Avenue West) and pre-restoration assessment of site 7076 (Perch Lake) was requested by St. Louis Estuary AOC managers. Benchmark site 7049 was not sampled in 2021 due to logistical and time constraints, however, vegetation sampling will take place next year in 2022. More details regarding the Perch Lake site are discussed in subsequent sections below.

Panel Survey Results

Vegetation sampling for CWM panel sites began July 8, 2021 and ended July 27, 2021. In general, the most common plants encountered across the western basin in 2021 included cattails, common reed grass (Phragmites), wetland sedges, purple loosestrife, watermilfoil, coontail and duckweeds. In total, eleven non-native species were encountered during the 2021 surveys: *Typha x glauca* (hybrid cattail), *Typha angustifolia* (narrowleaf cattail), *Phragmites australis* (non-native common reed), *Lythrum salicaria* (purple loosestrife), *Phalaris arundinacea* (reed canary grass), *Myriophyllum spicatum* (Eurasian watermilfoil), *Nasturtium officinale* (watercress/ yellowcress), *Potamogeton crispus* (curly-leaf pondweed), *Ambrosia artemisiifolia* (common ragweed), *Tanacetum vulgare* (tansy), and *Hydrocharis morsus-ranae* (European frogbit).

Typha x glauca (hybrid cattail, an invasive, see Fig. 29) was encountered at the following panel sites: 1096, 1469, 1152, 1697, 7033, 1449, 1458, 1698, 1519, 1459. *Typha angustifolia* (narrowleaf cattail, also invasive) was encountered at the following panel sites: 1152, 1441, 1720, 1449, 1698, 1497, 1519, 1456, 1459. Invasive *Phragmites australis* was encountered at the following panel sites: 1449, 1456, 1459, 1745. *Lythrum salicaria* was encountered at the following panel sites: 1096, 1088, 1152, 1697, 7033, 1449, 1698, 1456, 1459, 976, 979. *Phalaris arundinacea* was encountered at the following panel sites: 1088, 1469, 1720, 7033, 1449, 1459, 1732, 1745, 974. *Myriophyllum spicatum* was encountered at the following panel sites: 1469, 1441, 1720, 1697, 1449, 1458, 1497, 1456, 1459, 974. *Potamogeton crispus* was encountered at the following sites: 1469, 1441, 1458, 1497, 1456, 1459. *Nasturtium officinale, Ambrosia artemisifolia, Tanacetum vulgare* and *Hydrocharis morsus-ranae* was encountered at panel sites 1088, 1456, 1745, and 7033, respectively.

Figure 29. R. Rutherford and J. Hartsock in a Typha stand in a Green Bay coastal wetland.

Of the 24 panel sites sampled, sites 1076, 969, 943, and 972 were the only sites with no non-native species encountered in sampling plots along the research transects. We encountered and reported *Myriophyllum spicatum* (Eurasian watermilfoil) at site 974 (Sand Point Wetland), which had not been encountered in previous years, but total cover was quite low (1%). We also encountered the State Threatened pondweed *Potamogeton vaseyi* (Vasey's pondweed) at Sand Point Wetland.

Of note, on August 9, 2021, our finding of European frogbit at site 7033 (Oconto Marsh #2) was quickly published online by the Wisconsin Wetlands Association (https://www.wisconsinwetlands.org/updates/new-wetland-invasive-plant-discovered-in-wisconsin-european-frog-bit/) to inform essential organizations. Unfortunately, extensive monitoring of the area by the Wisconsin DNR revealed severe infestation throughout the coastal area ranging from the city of Oconto to the city of Marinette (*see attached map*). Many of these infested sites are state properties including numerous State Natural Areas. Per the advice of the European frogbit Collaborative, WDNR worked to hand pull smaller isolated sites (~2,000 lbs.) leaving the larger dense sites for an early summer treatment next year.

Extra Sites and Data

Benchmark site 7049 (21st Avenue West) was not sampled due to logistical challenges and time constraints. Vegetation surveys will be conducted at site 7049 next year in 2022.

Benchmark site 7076 (Perch Lake) was sampled on July 8, 2021. The pre-restoration assessment was requested by St. Louis Estuary AOC managers. The proposed restoration of Perch Lake will involve replacing the culverts under the road with a bridge or box culvert to create a better connection with the river and hopefully create more water exchange to improve the quality of Perch Lake. Dominant submergent zone vegetation included *Ceratophyllum demersum*, *Nuphar variegata*, *Nymphea odorata*, *Potamogeton zosteriformis*, and *Elodea canadensis*. All submergent zone vegetation encountered were native species. Dominant emergent species included *Typha latifolia*, *Typha angustifolia* (invasive), and *Typha x glauca* (invasive). The sedge *Carex stricta*, a desirable wet meadow sedge, was dominant in the wet meadow zone. Non-native species included: *Typha x glauca*, *Typha angustifolia*, and *Lythrum salicaria*.

Wetland Condition Observations and Results

Water levels were markedly lower at Lake Michigan sites than in 2020. However, based on species counts from previous years of monitoring, we continued to see trends of reduced plant species richness at most sites across the western basin and wet meadow zones were rarely present. We also observed that sites behind causeways contained considerably more chaff/ standing dead litter than non-protected/ exposed lacustrine wetland sites. These protected sites were especially species poor, dominated by *Typha* sp. or *Phragmites australis*, and typically harbored only 1 – 2 plant species per quadrat. Lastly, at some sites, we saw signs areas previously occupied by alder trees (that have died due to high water levels) are being replaced by wet meadow flora.

Data Processing

All vegetation data has been entered into the CWM database. QC checks will commence in the following weeks.

Mid-season QC Check Findings
Dr. Danz was unable to go in the field this year due to Covid restrictions on personnel working together. However, longtime contractor Rutherford worked with newer staff to ensure consistency of sampling.

Audit and QC Report and Findings
Data was entered after all wetland sites were surveyed. No issues have been detected. QC checks will commence in the following weeks.

Additional Funding and Projects
In addition to CWM work, our second major project that complements CWM entails sampling aquatic macrophytes at several sites in the St. Louis River Estuary for the Minnesota Pollution Control Agency (MPCA). MPCA is currently developing a comprehensive, long term plan to delist the St. Louis River Area of Concern (AOC) through restoration efforts under a grant from USEPA and other project partners. The monitoring and assessment of aquatic macrophytes and soil at several sites in the estuary at various pre- and post-restoration stages will be used in the AOC delisting process. In 2021, 430 aquatic macrophyte plots were sampled across five MPCA sites (e.g., Munger Landing, Kingsbury Bay, SLRIDT Superfund Site, Grassy Point, and 40th Avenue), located on the Minnesota side of the St. Louis River. While sampling methods for MPCA wetland monitoring are slightly different from CWM methods (i.e., MPCA uses spatial grid sampling and is more concerned with submersed vegetation) the project goals are much the same, assessing the general health of the various wetlands sampled. Of note, during MPCA sampling we observed and managed to obtain photographs of several shore-birds using sandbars. A migrating Baird's Sandpiper at the 40th avenue site was among the more exciting finds (Figure 30).

Figure 30. Baird's Sandpiper at site 7048 (benchmark 40th Ave West site, Duluth, MN). Photograph by Jeremy Hartsock.

Other Collaboration Activities

We have continued to rely on contractor botanist Ryne Rutherford to assist with our vegetation sampling at Green Bay and Upper Peninsula sites. We plan on collaborating with Ryne on future UWS research papers.

We recently received a request by Cherie Hagan with the Wisconsin DNR to add the "Michelle Wheeler Wetland" restoration site as a CWM Benchmark site. The UWS/NRRI teams will survey the new benchmark site in 2022 using traditional CWM methods.

Other Data Requests

Vegetation data for Mud Lake (Benchmark site 7064) was requested by Dan Breneman of the MPCA to assist planning for future restoration efforts at the site.

Related Student Research

N/A

University of Wisconsin-Green Bay Bird and Anuran Team

Team Members

PI Robert Howe; Team Leader Erin Giese; field crew Demetri Lafkas, Brenna Nicholson, Jarod Siekman-VerBoort, Nate Schwartz, Brandon Byrne, Jacob Woulf.

Training

Training was conducted from March-May 2021 at the University of Wisconsin-Green Bay. All field team members were required to pass an online test of identification designed by the bird/anuran teams during the past decade. Team Leader Erin Giese met with team members who were responsible for identification of birds and anurans both individually and as a group to review anuran and bird calls, protocols, and field safety prior to field data collection. She also conducted field training sessions with new members to ensure that protocols were followed, equipment was being used correctly, and team members were capable of acquiring accurate information. Training materials are available upon request from giesee@uwgb.edu.

Challenges and Lessons Learned

High lake water levels continue to create challenges in accessing points; in fact, some points now have little or no emergent wetland vegetation within 100 m of historical sampling localities. We used boats to reach 10 bird-only points at 4 wetland sites (4 points by motor boat, 6 points by kayak).

Site List

Despite high water levels, we sampled a record number of points (76) during 2021, covering 32 wetlands (14 in Wisconsin, 18 in Michigan [8 in the Escanaba area and 10 in the eastern Upper Peninsula]). Anuran surveys were conducted at 28 of these wetlands. Bird surveys were completed at all 28 anuran sites plus 3 bird-only wetlands. A final wetland was visited for birds, although it was classified as a "could not sample" site because the wetland habitat was entirely inundated. We did sample birds at this site for the sake of historical continuity and future water level analyses.

Of the 31 total regular panel sites we surveyed, two of them were benchmarks, three were re-sample sites, and three were pre-sample sites; we surveyed one non-panel special benchmark site (619 in the eastern Upper Peninsula of Michigan). We were not able to survey 11 panel sites due to access-related reasons such as 1) no road access, 2) remote island, 3) private land for which we could not connect with a land owner, or 4) could not acquire necessary permits (e.g., site 1373 - after submitting a permit application, we repeatedly contacted the agency and received no response).

Multiple sample points are surveyed at many of our wetland sites. Overall, we sampled 76 points (including the one point at the "could not sample" site 1678), 54 for anurans and 76 for birds. The number of officially sampled points (75) ties for the highest number of points ever sampled by the UW-Green Bay field team. Points were fairly evenly divided between Wisconsin (36 points) and Michigan (39 points: 19 in the Escanaba area and 20 in the eastern Upper Peninsula).

Panel Survey Results

Anurans

Our first surveys of the 2021 season took place on April 28, 2021 at sites 1697 and 1698 in Suamico and Little Suamico, Wisconsin. Our last surveys occurred in the far eastern Upper Peninsula of Michigan on July 10, 2021 at sites 792 and 878. Cumulatively across all sites and samples, we recorded eight anuran species, including American toad, spring peeper, gray treefrog, green frog, northern leopard frog, wood frog, chorus frog, and bullfrog, which are each relatively common and expected species to detect in Great Lakes coastal wetlands. We did not detect any uncommon or unusual anuran species. At 25 of our 162 total point count surveys, we did not detect any anurans calling at sites primarily along the west shore of Green Bay with a few in Upper Michigan.

Birds

Our first field surveys of the 2021 season were conducted on May 26, 2021 in lower Green Bay and Sturgeon Bay at sites 1441 and 1426. Our last surveys took place on July 9, 2021 at site 1698 in Little Suamico, Wisconsin. Cumulatively across all sites and samples, we recorded 124 bird species, including many target marsh birds, such as Pied-billed Grebe, Least Bittern, American Bittern, Sora, Virginia Rail, Marsh Wren, Sedge Wren, Swamp Sparrow, American

Coot, Common Gallinule, and Yellow-headed Blackbird. At sites 613 and 619, we documented Mute Swan, which is an invasive species that can negatively impact native swans. We also recorded several observations of invasive European Starlings (sites 1441, 1456, 1469, 1697, 1698, and 1732), House Sparrows (sites 1458 and 1697), and Rock Pigeons (site 1720). European Starlings and House Sparrows can outcompete native birds (e.g., Tree Swallows, Purple Martins) for nest sites. We detected multiple listed and special concern species, including Black Tern (sites 792, 796, and 1497), Caspian Tern (sites 660, 751, 1426, 1449, 1456, 1458, 1459, 1469, 1697, and 7031), Common Tern (sites 792, 1449, 1458, and 1459), Forster's Tern (sites 1459 and 1697), Great Egret (sites 613, 1441, 1449, 1458, 1459, 1469, 1515, 1519, 1681, 1697, 1698, 1732, 1743, and 7031), and Purple Martin (sites 1441, 1449, 1456, 1458, 1459, 1469, 1697, and 1698).

Extra Sites and Data

We surveyed one non-panel, special request benchmark site, namely Duck Bay Wetland site 619 in the eastern Upper Peninsula of Michigan, per our own request. We aimed to boost the sample size of the "high quality" and "low quality" ends of the environmental gradient for indicator development and sampled this site for birds via motor boat. This site was identified by the landuse and water quality (sumrank) indicator as a high quality "reference" site both during low and high water and was a memorably high-quality site based on Giese's visit in 2016. One of the two points we surveyed was almost entirely drowned out, though the second point still had a substantial stand of cattail and bulrush. We detected only a few target marsh birds, such as Pied-billed Grebe and Swamp Sparrow, though not nearly as many as we had hoped.

Wetland Condition Observations and Results

High water levels again made sampling challenging. One site (wetland 1678 in northern Door County, Wisconsin) failed to meet project criteria because it was totally covered with water, though we sampled it anyway for the sake of sampling continuity. Status of the wetland was noted in the submitted online site notes and status (as "could not sample").

As we have done almost annually since the beginning of CWMP, we once again surveyed site 792, which is considered one of the highest quality wetlands in the entire Great Lakes system. We documented key marsh bird species, including Black Tern, American Bittern, Common Gallinule, Marsh Wren, Pied-billed Grebe, Sora, Virginia Rail, Swamp Sparrow, and others.

Data Processing

All anuran and bird data have been double entered by field crew members and cross checked for QA/QC.

Mid-season QC Check Findings

Our team's newest anuran technicians were regularly checked throughout the field season by Erin Giese and Field Crew Leader Demetri Lafkas to ensure they were collecting data correctly.

Audit and QC Report and Findings

Double entries of anuran and bird data were compared for accuracy, and errors found between the entries were subsequently corrected.

Additional Funding and Projects

Because the field season began before the UW-Green Bay grant subcontract had been formally administered, we used funding from the Cofrin Center for Biodiversity at UW-Green Bay to pay field staff and to cover travel costs. The budget savings will enable us to conduct additional data analyses and outreach during 2021-2022, which otherwise would have been covered by the Cofrin Center for Biodiversity as part of this ongoing collaboration.

Other Collaboration Activities

We contributed major quantitative analyses and writing to the State of the Lakes 2022 Indicator Condition and Trends Report. These results will be expanded in the form of at least two manuscripts that we plan to submit for publication during late 2021.

Other Data Requests

Occurrences of American toad and green frog in the Lower Green Bay and Fox River Area of Concern were provided to a UW-Green Bay undergraduate student who completed a GIS class project on their occurrences in high and lower water in fall 2020. She later presented her research at the Wisconsin Wetlands Association Conference (see section below).

In July 2021 Audubon Great Lakes (AGL) requested CWMP bird data in order to assist them with assessing the impact of National Fish & Wildlife Foundation’s Sustain Our Great Lakes (SOGL) Program on waterbirds, which includes breeding marsh birds. In order to assess the impact of SOGL funding, they will implement a Before-After-Control-Impact study design, which includes compiling bird survey data that were collected prior to the onset of SOGL funding. CWMP marsh bird data would be used as part of the “before” treatment data set. AGL will also implement surveys beginning as early as fall of 2021 (representing the “after” treatment), which will be compared to survey data collected prior to 2021. CWMP data may also guide potential survey point locations for these surveys. CWMP PIs unanimously agreed to proceed with sharing their data and will collectively write a data sharing agreement with AGL over the coming months. Erin Giese is AGL’s main point of contact for this exchange.

Related Student Research

During early 2021 UW-Green Bay master’s degree student Tara Hohman, along with our CWMP research team and Dr. Amy Wolf of UW-Green Bay, published an article in the *Journal of Great Lakes Research*. The paper was based on data from the Great Lakes Coastal Wetland Monitoring Program between 2014 and 2019.

Hohman, T.R., Howe, R.W., Tozer, D.C., Giese, E.E.G., Wolf, A.T., Niemi, G.J., Gehring, T.M., Grabas, G.P. and Norment, C.J., 2021. Influence of lake levels on water extent, interspersion, and marsh birds in Great Lakes coastal wetlands. Journal of Great Lakes Research, 47(2), pp.534-545.

In February 2021, UW-Green Bay undergraduate student Britney Hirsch presented her fall 2020 GIS class project at the 2021 Wisconsin Wetlands Association Conference, which featured how anuran occurrences of American toads and green frogs change during high and low water levels in the Lower Green Bay and Fox River Area of Concern.

Hirsch, B. E.E. Gnass Giese, and R. Howe. 2021. Anuran Occurrences in High and Low Water within the Lower Green Bay & Fox River AOC. Wisconsin Wetlands Association Conference, Virtual. Poster Presentation. February 2021.

Central Michigan University Bird and Anuran Team

Team Members

The Central Michigan University (CMU) Team consisted of PI Dr. Thomas M. Gehring, returning graduate student crew leader Kylie McElrath, new graduate student crew leader Megan Bos, full-time technician Bridget Wheelock, and new undergraduate student technicians Olivia Buzinski and Madeline Garcia.

Training

Anuran training was completed 2 February 2021 and bird training was completed 12 May 2021 at CMU. Training involved instructing individuals on how to conduct standardized field surveys, on basic travel procedures, and on appropriate field safety measures. Individuals were trained to proficiently complete field sheets. Rules for site verification, safety issues including caution regarding insects (e.g., Lyme's disease), GPS and compass use, boat safety, working near traffic or roadways, and record keeping were also included in field training to insure that the guidelines in the QAPP were being followed.

All individuals involved in conducting the surveys passed each of the following tests on 1) anuran calls, 2) bird vocalization, and 3) bird visual identification via an on-line testing system established at the University of Wisconsin, Green Bay – see http://www.birdercertification.org/GreatLakesCoastal. Training documents, including SOPs and QAQC measures , specifically related to sampling procedures are available on the program website – see https://www.greatlakeswetlands.org/Sampling-protocols.vbhtml.

Challenges and Lessons Learned

N/A

Site Visit List

We surveyed 33 wetland sites, of which 3 were benchmark sites (515, 7061 and 7075). Sites 515 and 7061 were benchmarked by Dr. Don Uzarski because they represent low and high extremes, respectively, along the disturbance gradient and have long-term data sets. Site 7075 was requested as a benchmark by the United States Geological Survey (USGS) to monitor restoration progress. Of the original number of wetlands, we were assigned to sample (n = 46), we web rejected 1 site (566) and visit rejected 4 sites (442, 455, 485 and 597). There were 8 sites that could not be accessed either due to land ownership permission issues (428, 532, 554, 555 and 677) or because they were island sites that were unsafe to sample (466, 548 and 1604). There were 2 sites (473 and 474) that could not be sampled for anurans due to safety concerns with boating at night.

Panel Survey Results

Anurans: First sampling date 7 April 2021 Last sampling date 9 July 2021

Birds: First sampling date 20 May 2021 Last sampling date 9 July 2021

List of taxa detected in 2021

Anurans
American Toad (*Anaxyrus americanus*)
Bullfrog (*Lithobates catesbeiana*)
Chorus Frog (Western/Boreal) (*Pseudacris triseriata/Pseudacris maculata*)
Cope’s Gray Treefrog (*Hyla chrysoscelis*)
Gray Treefrog (*Hyla versicolor*)
Green Frog (*Lithobates clamitans*)
Northern Leopard Frog (*Lithobates pipiens*)
Spring Peeper (*Pseudacris crucifer*)
Birds
Alder Flycatcher
American Bittern
American Crow
American Goldfinch
American Kestrel
American Redstart
American Robin
American Tree Sparrow
American White Pelican
American Woodcock
Bald Eagle

Baltimore Oriole
Barn Swallow
Belted Kingfisher
Black Tern
Black-capped Chickadee
Black-crowned Night Heron
Black-throated Blue Warbler
Black-throated Green Warbler
Blue Jay
Blue-winged Teal
Blue-winged Warbler
Brewer's Blackbird
Brown Thrasher
Bufflehead
Canada Goose
Cedar Waxwing
Chipping Sparrow
Common Gallinule
Common Grackle
Common Merganser
Common Raven
Common Tern
Common Yellowthroat
Double-crested Cormorant
Downy Woodpecker
Eastern Kingbird
European Starling
Field Sparrow
Forster's Tern
Gray Catbird
Great Blue Heron
Great Egret
Great Horned Owl
Green Heron
Hairy Woodpecker
Herring Gull
Horned Lark
House Finch

House Sparrow
Killdeer
Least Bittern
Mallard
Marsh Wren
Merlin
Mourning Dove
Mute Swan
N. Rough-winged Swallow
Northern Cardinal
Ovenbird
Pied-billed Grebe
Pileated Woodpecker
Purple Finch
Purple Martin
Red-breasted Nuthatch
Red-eyed Vireo
Redhead
Red-winged Blackbird
Ring-billed Gull
Ruffed Grouse
Sandhill Crane
Song Sparrow
Sora
Spotted Sandpiper
Swamp Sparrow
Tree Swallow
Trumpeter Swan
Turkey Vulture
Unidentified duck
Unidentified flycatcher
Unidentified gull
Unidentified large bird
Unidentified swallow
Unidentified Tern
Unidentified woodpecker
Veery
Virginia Rail

Warbling Vireo
Whip-poor-will
White-throated Sparrow
Willow Flycatcher
Wilson's Snipe
Wood Duck
Yellow Warbler

Extra Sites and Data

Site 7075 was requested as a benchmark by the United States Geological Survey (USGS) to monitor restoration progress at the Shiawassee National Wildlife Refuge where diked units have been reconnected to the riverine system.

Wetland Condition Observations and Results

N/A

Data Processing

All 2021 bird and anuran data have been successfully double entered. All 2021 GPS waypoints have been uploaded and matched.

Mid-season QC Check Findings

On 22 June 2021, mid-year QC checks were completed for each crew leader/data collector (Megan Bos, Kylie McElrath, Bridget Wheelock) at 2 sites each for anurans and birds this year. Data collectors were 100% proficient in the performance criteria including: 1) correct location of sampling points; 2) accuracy of species-level identification; 3) accuracy of abundance category estimates; 4) correct criteria and techniques used for identification of rare species; and 5) correct use of field survey forms.

Audit and QC Report and Findings

All 2021 bird and anuran data have been successfully double entered. All 2021 GPS waypoints have been uploaded and matched. There were no issues.

Additional Funding and Projects

N/A

Other Collaboration Activities

N/A

Other Data Requests

N/A

Related Student Research

N/A

US Central Basin Fish, Invertebrate and Water Quality Team

Team Members

The US Central Basin Fish, Invertebrate and Water Quality Team consists of PIs and members from the following universities: Central Michigan University (CMU), Grand Valley State University (GVSU), Lake Superior State University (LSSU) and University of Notre Dame (UND). The PIs include Drs. Donald G. Uzarski (CMU), Carl Ruetz III (GVSU), Ashley Moerke (LSSU) and Gary Lamberti (UND).

The CMU field crew consisted of full-time technician Bridget Wheelock (field crew leader since 2018), graduate student technician Derek Hartline (formerly LSSU undergraduate technician) and undergraduate student technician Conor Judge. In the lab CMU had full-time technician Molly Gordon as lead invertebrate taxonomist and graduate student Corrin Logan as water quality technician.

The GVSU crew consisted of incoming graduate student and new crew leader Matthew Silverhart (returning crew member from 2020), returning graduate student technician Nick Vander Stelt, and new crew members Brandan May (undergraduate) and Victoria Vander Stelt (temporary technician). The LSSU team members consisted of full-time technician, team leader and invertebrate taxonomist Jessica Wesolek, crew chiefs Avery Feldmeier and Savannah Blower (both returning undergraduate students), and new undergraduate crew member Michael Hillary.

The UND team members consisted of Sarah Klepinger (crew leader since 2019), and two undergraduate summer technicians (Corbin Hite and John Paul Lewis). In addition, the UND graduate students took turns coming out to assist the UND crew at each field site. These students were Katherine O'Reilly, Whitney Conard, and Alison Zachritz. As well as being crew leader, Sarah Klepinger is also the Lamberti lab manager. She will stay with the Lamberti lab to process all 2021 samples and data, and to provide continuity for the 2022 field season.

Training

Central Michigan University hosted the Central Basin training at sites 515 and 517 in Saginaw Bay on 8 June 2021 and 9 June 2021. The training was led by CMU crew leader Bridget Wheelock who has been part of the CWMP since 2012. The topics covered were water quality collection, *in situ* data collection, filtering, titration, GPS navigation, site/zone selection, invertebrate sampling and picking, fyke net setting and retrieval and fish handling. Each team used their own equipment to familiarize themselves with the equipment.

Matthew Silverhart and Nick Vander Stelt (GVSU) received their sampling training and certification during the 2020 field season. Matthew was recertified and certified to be a crew leader and Brendan May and Victoria Vander Stelt were trained on the field sampling protocols at the Central Basin training. All crew members were always directly supervised by Matthew Silverhart in the field. Matthew Silverhart was trained by Travis Ellens, who was a crew leader from 2014-2020, on how to enter data into the database following the field season.

The pandemic prevented the UND team from attending any annual training with other teams. Instead, the crew went out on a local lake and practiced setting fyke nets, collecting invertebrates, and taking water samples. All members had been fully vaccinated and maintained a safe distance and avoided public places as recommended by the University and the CDC.

Prior to the Central Basin training, the LSSU team did additional training with LSSU PI Dr. Ashley Moerke. Fish ID training was conducted in Crawford Science Hall using preserved specimens. GPS training also occurred here during this time. Initial field training was provided by LSSU PI (Moerke) at Ashmun Bay where the crew went through the entire equipment deployment and sample collection process.

Challenges and Lessons Learned

The LSSU team had a few maps of sites that had inaccurate polygons and the maps had to be remade. There were no other challenges besides continuing to conduct the sampling safely during the pandemic as recommendations adapted to the current conditions.

Site Visit List

The US Central Basin was assigned 54 sites (29 CMU, 7 GVSU, 11 LSSU, 7 UND), three of which were benchmarks (7061, 515 and 7075). Sites 515 and 7061 were benchmarked by Dr. Don Uzarski because they represent low and high extremes, respectively, along the disturbance gradient and have long term data sets. Site 7075 was requested as a benchmark by the United States Geological Survey (USGS) to monitor restoration progress. We sampled 39 sites, visit rejected 12 and could not access three sites (1584 due to land ownership issues, 5210 and 5078 because they are located in Canada and the Canadian border was closed due to the pandemic).

Panel Survey Results

Sampling began on 8 June 2021 and the last site was sampled on 20 August 2021. The following tables list non-native species by site and reptile and amphibian species captured in fyke nets, respectively.

<u>Non-native Species by Site</u>

Site	Common Name	Taxa name
473	Rainbow Smelt	*Osmerus mordax*
473	Round Goby	*Neogobius melanostomus*
474	Round Goby	*Neogobius melanostomus*
494	Common Carp	*Cyprinus carpio*
494	Round Goby	*Neogobius melanostomus*
515	Round Goby	*Neogobius melanostomus*
536	Round Goby	*Neogobius melanostomus*
539	Round Goby	*Neogobius melanostomus*
548	Round Goby	*Neogobius melanostomus*
590	Round Goby	*Neogobius melanostomus*
613	Round Goby	*Neogobius melanostomus*
613	Rusty Crayfish	*Orconectes rusticus*
660	Round Goby	*Neogobius melanostomus*
778	Alewife	*Alosa pseudoharengus*
778	Freshwater Tubenose Goby	*Proterorhinus semilunaris*
786	Rusty Crayfish	*Orconectes rusticus*
816	Rainbow Smelt	*Osmerus mordax*
1267	Round Goby	*Neogobius melanostomus*
1308	Goldfish	*Carassius auratus*
1325	Common Carp	*Cyprinus carpio*
1598	Round Goby	*Neogobius melanostomus*
1604	Rusty Crayfish	*Orconectes rusticus*
1898	Common Carp	*Cyprinus carpio*
1898	Goldfish	*Carassius auratus*
1898	White Perch	*Morone americana*
1904	Common Carp	*Cyprinus carpio*
1904	Freshwater Tubenose Goby	*Proterorhinus semilunaris*
1904	Goldfish	*Carassius auratus*
1904	Round Goby	*Neogobius melanostomus*
1904	White Perch	*Morone americana*
1933	Common Carp	*Cyprinus carpio*
1933	Goldfish	*Carassius auratus*
1933	White Perch	*Morone americana*

Reptile and Amphibian Species Captured in Fyke Nets

Common Name	**Taxa name**
Common Snapping Turtle	*Chelydra serpentina*
Eastern Newt	*Notophthalmus viridescens*
Northern (Common) Map Turtle	*Graptemys geographica*
Northern Leopard Frog	*Lithobates pipiens*
Painted Turtle	*Chrysemys picta*
Spiny softshell	*Apalone spinifera*
Stinkpot (Common Musk Turtle)	*Sternotherus odoratus*

Extra Sites and Data

Sites 515 and 7061 were benchmarked by Dr. Don Uzarski because they represent low and high extremes, respectively, along the disturbance gradient and have long term data sets. These data will be used for developing and improving our indices of biotic integrity and indices of environmental condition. Site 7075 was requested as a benchmark by the United States Geological Survey (USGS) to monitor restoration progress at the Shiawassee National Wildlife Refuge where diked units have been reconnected to the riverine system.

Extra soil cores were collected by CMU and LSSU at a subset of sites for microplastics and metals analyses. These data are not entered into the CWM data management system and are stored on drives and hard copies at the CMU Wetland Ecology Lab. Hobo DO loggers were deployed at each site that was fished. These data were sent to Nathan Tuck and Jan Ciborowski at the University of Windsor and are not stored in the database. Additionally, sites 802, 806, and 878 were sampled by LSSU for fish earlier in the season and later in the season as part of an undergraduate study looking at changes in fish assemblages. Another LSSU undergraduate deployed detritus packs to quantify decomposition. These data were not entered in the database.

Wetland Condition Observations and Results

The CMU crew noted that water levels were lower than last year resulting in many shallow and sometimes dry wet meadow zones. *Phragmites* zones seemed more sparse than previous years. We only had issues with muskrats chewing holes in our nets at one site, which is fewer than in previous years.

The GVSU crew noted that compared to the previous year of sampling, the water levels across the sites visited have dropped significantly, allowing for more nets to be set by our crew than the previous year. Overall the wetlands sampled by the GVSU crew were accessible and did not show any severe disturbances.

The LSSU crew noted that water levels were high early in the season (i.e., early June) but dropped quickly in the river which resulted in some zones becoming dry (e.g., *Typha*).

The UND crew noted that while water levels were not as dramatically high as they were in 2020, they were high enough to make it difficult to find suitable fishing areas. In addition, vegetation (floating leaved and emergent) was often so thick that it also prevented setting nets (this was true in two sites in particular). Of the six vegetation zones sampled, three were fished. One zone had surprisingly robust predator populations (mainly muskrat and herons), and fishing success was inhibited because they tore holes in all of our nets. We did not meet the minimum number of required fish in that zone, but we decided not to reset nets for three reasons:

1: Thick vegetation and deep water limited where we could set our nets

2: Weather and net deployment were optimal during the first try, so there was no reason to think we would do better with a second try

3: We did not want to subject our equipment to further damage.

This decision was approved by our principal investigator, Gary Lamberti.

Most of the sites we surveyed were remote enough that we did not see much in the way of ecosystem disturbances, aside from the occasional floating debris. We did, however, see a great deal of wildlife, including blackbirds, herons, swans, grebes, and muskrat.

People we encountered often seemed curious about what we were doing. Even when were initially met with suspicion, once our motives and qualifications were explained, people became supportive. They responded positively when we explained that we were there to determine wetland health, and to keep the wetlands in good shape for fish and wildlife. The most common questions were regarding which fish we caught and where we caught them, as we have witnessed in previous field seasons. Overall, there was a general tone of enthusiasm about the project, especially from anglers.

Data Processing

All habitat, fyke and *in situ* field data have been entered and QA'd for all crews. Chlorophyll-a samples have been shipped to UND for processing. Water samples from LSSU and GVSU have been delivered to CMU for analysis. The GVSU macroinvertebrate samples have also been delivered to CMU for identification. Macroinvertebrate identification and QA has begun in the CMU and UND labs. By the annual meeting in February, all macroinvertebrates will be identified and we will bring samples to trade with our collaborating QA laboratory. Sample processing is expected to be finished in spring of 2022.

Mid-season QC Check Findings

The CMU mid-season check occurred 21 July 2021 at site 7061 and no issues were noted. The crew correctly located sampling points, collected data and identified fish species.

The GVSU mid-season QC check occurred on 8 July 2021 at site 1308 and no issues were noted. Dr. Carl Ruetz III joined the sampling crew and confirmed that the sampling protocols were being followed and that fish were being identified correctly in the field.

The LSSU mid-season check occurred 8 July 2021 at site 806 and no issues were noted. The crew was correctly sampling and identifying fishes in the field.

The UND mid-season QC check was conducted by PI Gary Lamberti on 20 July 2021 at site 1301. All field procedures QA/QC checked by the PI were found to follow GLCWMP SOPs.

Audit and QC Report and Findings

No issues currently

Additional Funding and Projects

For CMU, additional sites were sampled for a microplastics and sediment metals project and funded through other CMU funds.

For LSSU, there were three undergraduate projects discussed below.

Other Collaboration Activities

CMU collaborated with the University of Michigan, USGS and the US Fish and Wildlife Service to sample site 7075.

LSSU has been collaborating with Matt Cooper on an undergraduate project.

Other Data Requests

N/A

Related Student Research

As part of the related sediment project, CMU graduate student Corrin Logan is measuring sediment nutrients within soil cores in a subset of the 2021 coastal wetlands.

Three undergraduates from LSSU conducted their senior thesis research on projects related to the GLCWMP. One was evaluating macroinvertebrate assemblages between hardened and natural shorelines. A second student is quantifying litter decomposition in wetlands of varying health. A third student is evaluating fish assemblage changes throughout a summer in St. Mary’s River coastal embayment wetlands.

US Central Basin Vegetation Team

Team Members

The US Central Basin Vegetation Team consists of PI Dr. Dennis Albert, full-time CMU staff and crew leaders Allison Kneisel and Matthew Sand, CMU graduate student crew leader Olivia Anderson and 2 additional CMU summer field technicians. Allison, Matthew and Olivia are all returning crew members, while the summer field technicians were new.

Training

Allison Kneisel (4 years of crew leader experience) and Matthew Sand (2 years of crew leader experience) years trained Olivia Anderson (1 year of crew member experience) to be a field crew leader from June 21-22nd 2021 at the Galien River wetland. Topics covered included identifying zones for sampling, proper use of GPS for navigation, placing transects and plots, percent cover estimation, collection of plants for expert ID, and completion of datasheets.

Allison Kneisel, Matthew Sand, and Olivia Anderson trained the 2 new technicians on field sampling techniques in Mt. Pleasant wetlands on June 24th, 2021. Topics covered included, proper use of GPS for taking waypoints, percent cover estimation, collection of plants for expect ID, and completion of datasheets.

Dr. Dennis Albert led macrophyte identification training in several northern Michigan wetlands on June 28th-30th 2021. Crew members were tested on a subset of the specimens collected over the 3-day period. Crew leaders Olivia Anderson and Matthew Sand both correctly ID all test specimens, and the summer technicians both correctly identified approximately 85% of the specimens. Percent cover estimates were also compared with Dr. Albert during this training to ensure consistent sampling.

Challenges and Lessons Learned

While water levels were not as high as in 2018 and 2019, the patterns of vegetation zonation continue to be in flux with the wet meadow, emergent and submergent vegetation zones often being patchy or mixed. When samplers questioned how to treat zones, they sent pictures to one of the other crew leaders for confirmation and included information on the zonation in the notes section.

Site Visit List

The Central Basin vegetation crews sampled 43 sites, 39 panel sites and 4 benchmark sites. Two of the benchmarks were requested by Dr. Don Uzarski: sites 7061 and 515. Both sites represent extremes of the disturbance gradient (7061 low disturbance, 515 high disturbance) and have long term data sets. Two of the benchmarks were requested by Dr. Dennis Albert: sites 619 and

1546. Both of these sites have high diversity and are likely to respond to recent historically high water levels. Site 619 was part of this year's panel of sites and was only made a benchmark to ensure it did not fall below the too-many line.

There were 7 sites that crews could not access due to either landowner permissions (473, 474, 1584, 1373), no access point (605), or inability to cross the international boarder (5210, 5078). Two sites were rejected due to lack of wetland habitat and access issues, 597 and 566. Three sites exceeded the capacity of the sampling crews (867, 812, 1308).

Panel Survey Results

In the US Central Basin, the first day of vegetation sampling took place on June 21st, 2021, and the last day of sampling took place on September 8th, 2021. While specimen identifications and species lists are still underway, in general, we did not note any expansion of invasive species or encounter any threatened species. One of the less common bladderwort species, *Utricularia purpurea*, was found at Pointe Aux Chenes Marshes (site 1592) for the first time. The drop in water levels exposed new areas of wet meadow zone, resulting in a major increase in the number of native wet-meadow species that have been absent in recent high-water years.

Extra Sites and Data

Benchmark site East Saginaw Bay Coastal Wetland #5 (515) was sampled on August 23rd, 2021. It was selected as a benchmark to track a highly degraded site over a long period of time. This site continues to be dominated by invasive *Phragmites australis*, with few other vegetation species present.

Benchmark site Indian Harbor Wetland (7061) was sampled on July 20th, and was sampled in order to track a site that is relatively pristine over a long period of time. There were no obvious changes at this site from 2020 sampling.

Benchmark sites Hughes Point Wetland (1546) were sampled on September 9th. This site and Duck Bay are diverse and due to their location and hydrology are likely to be impacted by the recent water level changes. These sites will be compared to previous sampling events in the region to track the impacts of water level change.

The data for all these sites will be entered into the CWMP data management system.

Wetland Condition Observations and Results

As previously mentioned, the most visible trend noted by sampling crews is that the vegetation zonation was impacted by the high water levels. In many sites, the remains of dead woody plants persist in the wet meadow and emergent zones. There were also many seedlings in the wet meadow zones this year due to the lower water level than during the previous two years, exposing moist, aerated organic-rich sediments for seedling establishment.

Data Processing

Dr. Dennis Albert is finishing the last of the plant identifications and a CMU technician has started entering data. All data should be entered and quality checked by Spring of 2022.

Mid-season QC Check Findings

Allison Kneisel joined sampling crews the week of August 3rd in the St. Ignace region and the week of August 23rd in Saginaw Bay to evaluate sampling procedures. No corrections were needed for either sampling crew. Crews have also shipped plants of unknown or unsure plant identification to Dr. Dennis Albert for confirmation throughout the summer.

Audit and QC Report and Findings

A CMU technician has begun entering 2021 vegetation data into the CWMP database. When the entry is completed, data will be confirmed by a second technician or by a CMU staff member. Finally, all data will be reviewed by Dr. Dennis Albert. Any issues noted will be included in the Spring report.

Additional Funding and Projects

There is no additional funding to report for the 2021 field season.

Other Collaboration Activities

There are no external collaboration activities to report for the 2021 field season.

Other Data Requests

There are no vegetation data requests to report during the 2021 field season.

Related Student Research

CMU graduate student Olivia Anderson is using the transect locations and water depths from the vegetation data sets to map the inundation of coastal wetland vegetation as part of her master’s thesis work.

Canadian Central/Eastern basin Bird/Anuran team at Birds Canada, Port Rowan/Long Point, Ontario

Team Members

Our team consists of 1 permanent/year-round staffer and 4 temporary summer field technicians / contractors. All members returned this year after several consecutive years with the project, as indicated in parentheses in the list below.

- Doug Tozer, PI (11 years since 2011)

- Jeremy Bensette, Crew (8 years since 2014)
- Tim Arthur, Crew (5 years since 2017)
- Tyler Hoar, Contractor (11 years since 2011)
- Nadine Litwin, Contractor (11 years since 2011)

Training

All 4 summer field technicians / contractors received training refreshers via Zoom or phone in late March 2021. Topics included site selection procedures and station placement guidelines; specifics of anuran and bird survey field protocols; what's involved with reporting; safety procedures; overview of data entry; and GPS procedures. All members previously showed comprehension of the topics through written and practical in-person tests and successfully completed the online anuran and bird identification tests.

Challenges and Lessons Learned

Our field work was much less restricted by COVID-19 during 2021 compared to 2020. Even though there were public lockdowns and other restrictions in place in Ontario this year, especially during the early spring, they allowed for surveys to proceed with appropriate caution. This was not the case during 2020, when we were completely grounded and unable to work during much of the early part of the field season. Thus, we were able to complete all of our planned surveys this year. It was still stressful and challenging for staff to navigate through the details of working while under various restrictions and regulations, but we were able to overcome these challenges and got the work done safely.

Typically, in pre-COVID-19 years, a bird and anuran team from the US crossed the border into northern Ontario and surveyed a number of sites between Sault Ste. Marie and Manitoulin Island on Lake Huron. This, of course, was not possible in 2021 due to COVID-19 border-crossing challenges. So we pushed to the limit and beyond this year by piggy-backing on funds and effort from another project (Ontario Breeding Bird Atlas-3) and were able to survey most of these sites. Although we were able to pull this off this year, it is not something we will be able to sustain in the future. Hopefully the bird and anuran teams will be able to collectively return to our "normal" approach with unrestricted international border crossings in 2022.

Site Visit List

We considered 75 sites for sampling (well beyond our allotted capacity of 50 sites; see Challenges and Lessons Learned above), which consisted of 62 panel, 12 resample, and 1 special-request benchmark site. We surveyed 42 of these 75 sites. We were unable to survey 33 of the sites due to the following:

- issues with obtaining landowner access, including complications due to COVID-19 such as permit rejections and banned access to Indigenous communities (24 sites)

- safety (3 sites)
- excessive distance (> 800 km / 500 miles) from our home base (3 sites)
- lack of suitable bird or anuran habitat due to flooding (2 sites)
- lack of connection to the main lake (1 site)

Panel Survey Results

Sampling for anurans occurred from 7 April until 10 July and sampling for birds occurred from 15 May to 3 July. Of note were 95 point occurrences of 8 Ontario bird species at risk or of conservation concern, based on information currently in the database; totals for some of these species may increase slightly after a small amount of remaining data entry is completed in October.

		No. Occurrences	
Species	**ON-ESA/SARA Status***	**2020**	**2021****
Bald Eagle	Special concern	11	14
Bank Swallow	Threatened	12	11
Barn Swallow	Threatened	59	39
Black Tern	Special concern	7	11
Bobolink	Threatened	3	0
Chimney Swift	Threatened	2	4
Common Nighthawk	Threatened	4	1
Eastern Meadowlark	Threatened	3	0
Least Bittern	Threatened	25	14
Total		126	95

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

** Totals for 2021 are preliminary due to incomplete data entry; occurrences for some species may increase once data entry is complete.

Also of note were 2 occurrences of Chorus Frog, some populations of which are listed as threatened in Canada (vs. 8 occurrences in 2020). As with the bird occurrences reported above, this total may increase slightly after a small amount of remaining data entry is completed in October.

Extra Sites and Data

We collected bird and anuran data at 1 special request benchmark site: 5762 Point Pelee Marsh 2. This was requested by Parks Canada, who will use the information to help track the success of their restoration activities in the marsh. Of note at this site were point occurrences of the following bird species at risk or of conservation concern: Bald Eagle, Bank Swallow, Barn Swallow, and Black Tern. By contrast, we observed no at-risk anurans at this site.

We collected additional habitat data at each bird and anuran sample point following a slightly modified version of Birds Canada's Great Lakes Marsh Monitoring Program habitat sampling protocol. These data are being collected to augment species-habitat relationship models, particularly for certain marsh bird species, some of which are strongly influenced by local vegetation characteristics (i.e., within a few hundred meters of the sampling point), and are stored in an Access database on Birds Canada's secure servers in Port Rowan, Ontario.

Wetland Condition Observations and Results

We noted that water levels were relatively high at many of our sites, especially on Lake Huron. We sensed that abundance of secretive marsh birds was higher this year at sites with suitable emergent vegetation likely because of the higher levels. By contrast, these species were absent or at lower abundance at some sites with especially high water where emergent vegetation was relatively sparse. These observations are to be expected based on Homan et al. (2021), which used CWMP bird data from throughout the Great Lakes and across several years to document the relationship between fluctuating water levels and wetland bird occurrence and abundance.

Data Processing

Nearly all of of our data has been entered into and checked in the CWMP database; less than 5% remains to be entered, which will be completed in October.

Mid-season QC Check Findings

Mid-season checks were performed in mid-June; no issues were identified.

Audit and QC Report and Findings

No issues to report.

Additional Funding and Projects

Nothing to report.

Other Collaboration Activities

Nothing to report.

Other Data Requests

Nothing to report, but see student project descriptions in the next section.

Related Student Research

We provided analytical support and other guidance for 2 undergraduate projects. Sam Bosio, for his honors thesis at the University of Notre Dame, is using anuran, vegetation, and water quality data from the CWMP to investigate relationships between frogs and nonnative invasive plant species. Ethan VanValkenburg, as part of the Michigan Sea Grant Undergraduate Environmental Internship Program, is looking at the influence of various local and landscape factors on bird communities based on CWMP data. Although both of these projects are based on CWMP data from outside our area, we've been answering questions from the students specific to birds and anurans via email and online meetings, which greatly enhances the diversity of each of their training programs.

Canadian Central/Eastern Basin Fish, Invertebrate and Water Quality Team at the University of Windsor, University of Wisconsin River Falls, and Canadian Wildlife Service

Team Members:

Principal Investigators:	Jan Ciborowski, Paul Weidman (UWindsor) Joseph Gathman (UW River Falls) Joe Fiorino, Greg Grabas (CWS)
Permanent staff:	UWindsor – Li Wang, Michelle Dobrin, Stephanie Johnson, Anique Gauvin, Emilee Mancini
Field Crew:	CWS – Ian Smith (returning), Hayley Rogers (returning); Tineasha Brenot (new), Lauren Johnson (new)

Training:

University of Windsor: The field crew leader in 2021 was Stephanie Johnson (five prior years of experience on the project) who directly supervised all field sampling. Co-PI Joseph Gathman prescreened the suitability of sample sites but was unable to accompany the field crew because travel restrictions due to the COVID-19 pandemic prevented him from entering Canada. All crew members are certified for identifying common fishes and Species at Risk through the Royal Ontario Museum's course in fish identification.

All field crew members had worked on the project since 2017 and so only a review and refresher of protocols was needed. The review included instruction in GPS use, assessment of whether sites met project criteria (open water connection to lake, presence of a wetland, safe access), identification of vegetation zones to be sampled, water quality sample collection, preprocessing and shipping to water quality labs, calibrating and reading field instruments and meters, setting, removing, cleaning and transporting fyke nets, and protocols for collecting and preserving macroinvertebrates. Crews received refresher training and review in field data and lab entry. All field personnel were given refreshers in basic fish identification.

Canadian Wildlife Service (CWS) field crew members were trained by Joe Fiorino and Ian Smith. The sampling protocol, technical equipment use, occupational health and safety, and field-based decision-making were covered in detail over multiple days; staff were assessed in the field and lab for proper sample collection, data recording, GPS use, water processing, equipment calibration, and lab sample preparation and storage. An experienced staff member was paired with new personnel to reinforce project protocols and ensure high data quality.

Challenges and Lessons Learned

Water Quality Samples
Water quality sampling followed the protocols dictated by the QAPP as originally developed by the GLWMP water quality team. Metered measurements were made and water samples were collected at the time that fyke nets were placed in the water. Water samples were stored refrigerated on ice in darkness until they were returned to the laboratory at the end of a field trip. All laboratory analyses were conducted by Environment and Climate Change Canada's National Laboratory for Environmental Testing (NLET) in Burlington, ON. However, restrictions imposed by the COVID-19 pandemic resulted in the lab's closure until September 2021. As a result, all samples collected in 2020 were stored frozen and were sent to NLET in late summer 2021, when laboratory activities resumed. The one exception was Chlorophyll *a* samples (which were shipped to colleagues at the University of Notre Dame for analysis). Field-based measurements are currently being entered into the water quality database.

Water levels and wetland availability
Lake levels were noticeably lower in 2021 compared to summer 2020 (30 cm minimum, by observation). Many marinas had renovated their boat launch docks to be higher to accommodate the rising water levels over the past few years. However these docks now appeared significantly raised due to the drop in water levels this summer. Some marinas had posted signs warning of low water levels in the ramps, and advised boaters to raise their boat motors prior to launching.

Over the past few years of high water, wet meadows in some wetlands were beginning to re-establish in new areas of low water (usually areas that were formerly shoreline, but were now underwater), while areas that were previously meadows were becoming submerged and thinned out by the higher water. The lower water levels observed this summer resulted in the newly-formed wet meadows being either minimally flooded or completely dry at the time that most wetlands were visited. This prevented us from setting nets in most wet meadows this summer, although it allowed us to fish more Typha zones than had been possible in the previous few years (Typha zones can often be quite deep limiting our ability to set nets - especially on Lake Huron).

Weather patterns were quite different this summer compared the previous 5-year cycle. We often encountered high winds and heavy rain/thunderstorms in all regions that we sampled throughout the summer.

Lake Ontario water levels were well below the long-term average in 2021 (an unintended consequence of efforts to mitigate flooding in early 2021). The influence of low-water conditions seemed to be pronounced. The CWS team observed increased interspersion among vegetation types (e.g., meadow species mixed with cattails, lilies mixed with SAV), an apparent increase in meadow marsh extent, an apparent increase in the number of non-native plants (especially *Lythrum salicaria),* and fewer patches of floating *Typha* mats.

Site Visit List
The CWS crew visited and evaluated 12 sites along the north shore of Lake Ontario. All sites were sampled. The University of Windsor crew was assigned 3 Lake Ontario sites, one of which (Grafton Swamp – 5358) had to be rejected because wind and waves made sampling unsafe.

The University of Windsor crew was initially assigned 34 sites on lakes Erie and Huron or the connecting channels. Of these, one was rejected when visited because there was no water in what remained of an old wet meadow polygon (Scott Point Wetland Complex 1, 5878). Two other sites were not visited by crews because we were unable to acquire access permits due to First Nations prohibitions in consideration of COVID risks (John's Bay 2, 5475 and Oak Bay 4, 5697 on Manitoulin Island). Another site (Dorcas Bay 2, 5244) was situated the Bruce Peninsula National Park, for which we lacked a sampling permit. Two other sites were too remote from shorelines and were deemed inaccessible (Lighthouse Point, 5527 and Long Point Wetland 6 5544). Therefore, the combined efforts of CWS and Windsor crews resulted in a total of 40 sites sampled: 14 on Lake Ontario, 6 on Lake Erie (all in Ontario), and 20 on the Ontario shore of Lake Huron or the St. Marys River.

Invertebrates and water samples were collected at 39 of the 40 sites that were accessible. Five sites were not sampled for fishes: Scott Point Wetland Complex 1 (5878), Tremblay Beach Marsh (5997), Ruscom Shores Marsh (5840), Penetang Marsh 2 (5723), and Point Pelee Marsh 2 (5762). Most of these sites could not be fished due to a combination of high water levels and unconsolidated sediment that exceeded the feasibility of the deep water fishing protocol.

Panel Survey Results/ Extra Sites and Data - *Benchmark sites*
Three benchmark sites were identified for sampling in 2021 - Point Pelee Marsh 2 (5762) and Hillman Marsh (5422) in Lake Erie, and Collingwood Harbour Marsh 5 in Lake Huron.

Point Pelee Marsh 2 and Hillman Marsh were sampled at the request of Parks Canada, who is conducting a 5-year restoration project to increase the amount of open water area at Point Pelee. Over the past 20 years, *Typha* coverage has expanded in many areas, reducing the extent of fish habitat including habitat for several Species-at-Risk, including Spotted Gar, Warmouth, Pugnose Shiners and Spotted Suckers. Unfortunately, we were unable to survey this benchmark this year for birds or anurans due to permitting challenges related to COVID.

Extra Sites and Data

Monitoring Short-term Variation in Dissolved Oxygen and Water Levels

In 2021, 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 m on samples of aquatic invertebrates and catches of fishes in fyke nets. We deployed one or more Onset Hobo dissolved oxygen (DO) loggers and 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). The CWS team deployed water level and DO loggers at 12 sites (on 1 net per site) visited in Lake Ontario. Loggers were left overnight and retrieved when the nets were pulled the following day.

University of Windsor Research Assistant Stephanie Johnson is receiving and compiling the basin-wide-scale water level data collected by participating CWM teams for 2021. We are still receiving records from the various CWM groups. In Canada, water level records were collected from 38 wetlands (14 on Lake Ontario, 6 on Lake Erie and 18 on Lake Huron). We have also received information on wetlands collected by Central Michigan University crews. Colleagues from other CWM teams will also contribute data from late season sampling efforts

Wetland Condition Observations, Results, and Significant Observations:

Non-native Species

Non-native fish species were caught by the CWS and Windsor teams at 12 of 14 sites sampled on Lake Ontario. Round Gobies were found at Pine Point Wetland 2 (5736), Black Creek Wetland (5098), Lower Napanee River 3 (5556), Sawguin Creek Marsh 10 (5869), Little Cataraqui Creek Complex (5531), Hay Bay Marsh 2 (5401) and Credit River Marshes (5213). They were also caught in Hillman Marsh 1 (5422) of Lake Erie; Baie Du Dore 2 (5016), Collingwood Harbour Marsh 5 (5187), and Quarry Island Wetland 2 (5792) on Lake Huron; and Lake Wolsley, (5516) and North Campbell Bay (5677) on Manitoulin Island.

Tubenose Gobies were caught at Sand Bay 2 (5856) on Lake Ontario, Muddy Creek (5654) on Lake Erie, and Hog Bay Wetland (5424), Sturgeon Bay Complex (5965), and Quarry Island Wetland 2 (5792) on Lake Huron.

Common Carp were caught at Sand Bay 2 (5856), Little Cataraqui Creek Complex (5531), Hay Bay Marsh 8 (5407), Toronto Island Wetlands 2 (5990), and Corbett Creek Mouth Marsh (5201) on Lake Ontario, and at Hillman Marsh (5422) on Lake Erie, and Hog Bay Wetland (5424) in Severn Sound of Lake Huron. Goldfish were caught at three locations - Jordan Station Marsh (5496), on Lake Ontario and Hillman Marsh (5422) and Muddy Creek (5654) on Lake Erie. Rudd were caught at two wetlands in Lake Ontario: Credit River Marshes (5213) and Jordan Station Marsh (5496). These were the first captures of Rudd by the University of Windsor fish team.

Species at Risk and Uncommonly Caught Species
Two species-at-risk were caught during the 2021 surveys. Two Warmouth were caught at Hillman Marsh (5422). Additionally, Northern Sunfish (*Lepomis peltastes*) were caught at Turkey Creek Marsh (5999) on the Detroit River and at Hog Bay Wetland (5424) and Quarry Island Wetland 2 (5792) on Lake Huron.

Additionally, a number of species were caught that have not been commonly captured in fyke nets by the CWM surveys in our region. Their appearance may be a reflection of several years of high water altering habitats that became accessible for netting during this year of declining water levels. Alternatively, or concurrently, the unusually high frequency of windy and rainy weather may have created wind-driven high water events, permitting fishes that might otherwise use deeper-water habitat to move into wetlands. Rain-associated freshets could also have carried stream-dwelling fishes into wetland habitats.

Unusual catches included
- a juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) at Sturgeon Bay Complex (5965) Lake Huron,
- 8 Creek Chub (*Semotilus atromaculatus*) from Corisande Bay 5 (5206)
- a Mottled Sculpin (*Cottus bairdii*) from Lake George 1 (5509) on Manitoulin Island
- a Muskellunge (*Esox masquinongy*) from Hog Bay Wetland (5424), Lake Huron
- Tadpole Madtom (*Noturus gyrinus*) from Hog Bay Wetland (5424) (9 individuals) and Quarry Island Wetland 2 (5792) (15 specimens)
- two Threespine Sticklebacks (*Gasterosteus aculeatus*) from Lake George 1 (5509)
- two Trout-perch (*Percopsis omiscomaycus*) from West Shore of St. Joseph Island 1
- a Walleye (*Sander vitreus*) from Buswell Bay (5139)

Sampling for fishes in Canada requires permits for Scientific Collection of Aquatic Species (Ontario Ministry of Natural Resources), compliance with the Province of Ontario's Environmental Protection Act (Ontario Ministry of Natural Resources), and Species At Risk (Fisheries & Oceans Canada). All permits had been approved both by CWS and by the University of Windsor at the start of the sampling season. Reports to the permit granting agencies have been completed in draft form and sent to both regional administrators. Records of fishes caught will also be sent to local conservation groups in Ontario where appropriate.

Reptiles

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

Eastern Snapping Turtles (*Chelydra serpentina*) were recorded at four of 14 Lake Ontario wetlands that were fished: Sand Bay 2 (5856), Parrott Bay Wetland 2 (5718), Credit River Marshes (5213) and Jordan Station Marsh (5496).

Painted Turtles (*Chrysemys picta*) were the most widespread species, with specimens caught at 18 locations. They were caught at eight of 14 Lake Ontario wetlands that were fished: Black Creek Wetland (5098), Lower Napanee River 3 (5556), Sand Bay 2 (5856), Hay Bay Marsh 8 (5407), Hay Bay Marsh 2 (5401), Toronto Island Wetlands 2 (5990), Wesleyville Marsh (5217), and Jordan Station Marsh (5496). Other specimens were caught at Hillman Marsh (5422), Lake Erie; Turkey Creek Marsh (5999), Detroit River; Desbarats Wetland 2 (5234), Findlay Point Wetland 1 (5280), Hog Bay Wetland (5424), North Campbell Bay, Manitoulin Island (5677), Point Au Baril 1 (5746), Tug Rock Wetland (5998), Lake Huron; and Richardson Creek Mouth, St. Joseph Island (5808).

Northern Map turtles (*Graptemys geographica)* were observed only at Hog Bay Wetland (5424) in Severn Sound of Lake Huron.

One Musk Turtle (*Sternotherus odoratus*) was caught at Parrott Bay Wetland 2 (5718) in Lake Ontario. One individual was captured at Point au Baril 1 (5746) and 14 specimens were caught at Tug Rock Wetland (5998) in Georgian Bay.

Our vegetation crews recorded sightings of snakes. Northern Watersnakes were observed at four locations: Corisande Bay 5 (Site 5206), Baie du Dore 2 (5016), Tug Rock Wetland (5998), and Hillman Marsh (5422). The CWS crew caught a Northern Watersnake in a fyke net (in a SAV zone) at Lower Napanee River 3 (5556).

Eastern Garter Snakes were found at Corisande Bay 5 (5206) and Baie du Dore 2 (5016).

Data Processing

All fish, vegetation, and field-collected water quality data have been compiled, are currently being entered into the databases and quality assured. Many of the macroinvertebrate samples collected by the Windsor team have been examined, identified to the family level, entered into the database, and the identifications quality checked according to QAPP protocols. Identification of invertebrate samples from the Lake Ontario sites sampled by CWS will begin shortly.

We have received, entered and Quality Assured laboratory analyses of water quality data from sites sampled in 2020, but are waiting to receive data from NLET for records from locations sampled during 2021 field season.

Mid-season QC Check Findings
No difficulties or anomalies were observed during mid-season checks, which were self-administered, both due to COVID19-related travel restrictions and protocols and since all field crew leaders have at least 5 years experience with the CWM teams.

Audit and QC Report and Findings
As mentioned above, all data entry is routinely QC'd by an experienced CWM team member within a few days of original entry.

Fish catches are reported annually to Fisheries and Oceans Canada as part of our permitting system. We are routinely asked to confirm the identity of unusual or difficult-to-identify specimens by scientists at the Royal Ontario Museum. We comply by sending voucher specimens and/or photographs. We have not been informed of any misidentifications over the past 5 years of sampling.

Additional Funding and Projects Project Leverage Examples
In 2021, the Canadian Wildlife Service (CWS) initiated a multi-year wetland monitoring program (the Protected Areas Wetland Monitoring Program) for National Wildlife Areas (NWAs) that follows CWMP sampling protocols. These data can be compared to the basin-wide CWMP dataset to assess and track wetland condition in NWAs over time. This monitoring program will provide critical information necessary to effectively manage these important ecosystems and will be used to support current and future CWS priority projects and programs (e.g., ongoing *Phragmites* management monitoring at Big Creek and Long Point National Wildlife Areas).

CWMP turtle observations collected from 2011 to 2020 were shared with the Natural Heritage Information Centre to support species at risk mapping and recovery planning. The CWS team will continue to share turtle observations with NHIC going forward.

Other Collaboration Activities and Collaborations
Over the last two years, Point Pelee National Park (PPNP) has been sampled as part of the CWMP to provide Parks Canada 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. Sampling at PPNP is planned to continue post-restoration.

In 2020, CWMP data on fishes, aquatic invertebrates, vegetation and water quality were used to establish criteria by which to delist several Beneficial Use Impairments in the Detroit River Area of Concern. Data from 2021 will be used to continue to refine these criteria.

In 2021, Meteorological Services of Canada was granted permission to use CWMP data on *Phragmites australis subsp. australis* and *Typha spp.* 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.

Other Data Requests

We occasionally receive requests for data from Canadian government agencies, which we refer to the project managers. The most recent request was from Environment and Climate Change Canada for fish data to support their Nearshore Framework assessment of Lake Erie habitat.

Related Student Research

One student completed his M.Sc. thesis this spring:

Tuck, N. 2021. Influence of environmental conditions on assessment of fish communities in two Lake Erie coastal wetlands. M.Sc. Thesis, University of Windsor. (J Ciborowski & J Gathman coadvisors)

One new PhD student, Pengfei Hou (2-year visiting PhD student from Yunnan University), is starting work this fall (2021) with Paul Weidman (supervisor at UWindsor, GLIER). Hou will be using remote sensing and spatial modeling approaches to analyze long-term variation in coastal wetland area and depth and water quality in nearshore regions of lakes Erie, Ontario, and Huron.

One postdoctoral fellow, Dr. Dylan Xia, is starting a short contract (4 months) this fall with Paul Weidman. Dylan will be analyzing spatial and temporal coherence in young-of-the-year forage fish and indicators of lower trophic level productivity in nearshore regions and coastal wetland sites in western Lake Erie.

Canadian Central/Eastern Basin Fish, Vegetation Team at the University of Windsor, University of Wisconsin River Falls, and Canadian Wildlife Service

Team Members:

Principal Investigators:	Jan Ciborowski, Paul Weidman (UWindsor) Joseph Gathman (UW River Falls)

	Joe Fiorino, Greg Grabas (CWS)
Permanent staff:	Li Wang (UWindsor); Ian Smith (CWS)
Field Crew:	UWindsor – Carla Huebert (team leader, returning) CWS – Hayley Rogers (taxonomist, returning); Tineasha Brenot, Lauren Johnson (new)

Training:
University of Windsor: The crew leader in 2021 was Carla Huebert (eight prior years of experience on the project) who directly conducted all vegetation field sampling. Co-PI Joseph Gathman prescreened the suitability of sample sites but was unable to accompany the field crew because travel restrictions due to the COVID-19 pandemic prevented him from entering Canada.

Carla Huebert has led the vegetation component of the project since 2013, and so only a review and refresher of protocols was needed as outlined in the QAPP. The review included instruction in GPS use, assessment of whether sites met project criteria (open water connection to lake, presence of a wetland, safe access), and identification of vegetation zones to be sampled, Carla also received refresher training and review in field data and lab entry to become familiar with changes to the database.

Canadian Wildlife Service (CWS) field crew members were trained by Joe Fiorino and Ian Smith. The sampling protocol, technical equipment use, occupational health and safety, and field-based decision-making were covered in detail over multiple days; staff were assessed in the field and lab for proper sample collection, data recording, and GPS use. An experienced staff member was paired with new personnel to reinforce project protocols and ensure high data quality. A mid field-season check was conducted in mid-August. No problems were identified.

Challenges and Lessons Learned
Water levels and wetland availability
Lake levels were noticeably lower in 2021 compared to summer 2020 (30 cm minimum, by observation). Many marinas had renovated their boat launch docks to be higher to accommodate the rising water levels over the past few years. However, these docks now appeared significantly raised due to the drop in water levels this summer. Some marinas had posted signs warning of low water levels in the ramps and advised boaters to raise their boat motors prior to launching.

Over the past few years of high water, wet meadows in some wetlands were beginning to re-establish in new areas of low water (usually areas that were formerly shoreline, but were now underwater), while areas that were previously meadows were becoming submerged and thinned out by the higher water. The lower water levels observed this summer resulted in the newly formed wet meadows being either minimally flooded or completely dry at the time that most wetlands were visited.

Weather patterns were quite different this summer compared the previous 5-year cycle. We often encountered high winds and heavy rain/thunderstorms in all regions that we sampled throughout the summer.

Lake Ontario water levels were well below the long-term average in 2021 (an unintended consequence of efforts to mitigate flooding in early 2021). The influence of low-water conditions seemed to be pronounced. The CWS team observed increased interspersion among vegetation types (e.g., meadow species mixed with cattails, lilies mixed with SAV), an apparent increase in meadow marsh extent, an apparent increase in the number of exotic plants (especially *Lythrum salicaria),* and fewer patches of floating *Typha* mats.

Site Visit List
The CWS crew visited and evaluated 12 sites along the north shore of Lake Ontario. All sites were sampled. The University of Windsor crew was assigned 3 Lake Ontario sites, one of which (Grafton Swamp – 5358) had to be rejected because wind and waves made sampling unsafe.

The University of Windsor crew was initially assigned 34 sites on lakes Erie and Huron or the connecting channels. Of these, one was rejected when visited because there was no water in what remained of an old wet meadow polygon (Scott Point Wetland Complex 1, 5878). Two other sites were not visited by crews because we were unable to acquire access permits due to First Nations prohibitions in consideration of COVID risks (John's Bay 2, 5475 and Oak Bay 4, 5697) on the North Shore of Lake Huron. Another site (Dorcas Bay 2, 5244) was situated in the Bruce Peninsula National Park, for which we lacked a sampling permit. Two other sites were too remote from shorelines and were deemed inaccessible (Lighthouse Point, 5527 and Long Point Wetland 6, 5544). Therefore, the combined efforts of CWS and Windsor crews resulted in a total of 40 sites sampled: 14 on Lake Ontario, 6 on Lake Erie (all in Ontario), and 20 on the Ontario shore of Lake Huron or the St. Marys River. Vegetation was sampled at all of these locations.

Panel Survey Results/ Extra Sites and Data - *Benchmark sites*
One benchmark site was identified for sampling in 2021: Point Pelee Marsh 2 (5762).

Also, Point Pelee Marsh 2 and Hillman Marsh (5422) were sampled in cooperation with Parks Canada, which is conducting a 5-year restoration project to increase the amount of open water area at Point Pelee. Over the past 20 years, *Typha* coverage has expanded in many areas.

Extra Sites and Data
None

Wetland Condition Observations and Results Significant Observations:

The most noteworthy observation in 2021 for the U. Windsor vegetation crew was the re-appearance of the wet meadow zone, particularly at the high energy lacustrine sites of Lake Huron – sites such as Scott Point (5878), Baie du Dore (5016, both on Lake Huron), and Richardson Creek Mouth (5808) and West Shore (6050, both on St. Joseph Island). These sites are not sheltered in a bay and the meadow zone is not protected by a huge stand of cattail fronting it. These are species-rich meadows, directly exposed along the shores of Lake Huron, with perhaps a thin stand of bulrush fronting them.

Record high water levels for the past several years resulted in many of these wet meadow communities being completely submerged by up to one meter of water, effectively drowning out most of the more sensitive plant species previously found growing there. In 2021, at the time of sampling (June - August), Lake Huron water levels were about 30 cm lower than their record highs of 2020. The receding water produced drier conditions in the wet meadow zones, thus permitting the vegetative seed banks to begin their regeneration process. The reappearing wet meadow zones of 2021 were characterized by narrow (1-3 m wide) strips of scattered vegetation bordering the shoreline. Most of the plants were noticeably smaller in size than the surrounding upland vegetation, presumably due to the very recent lowering of the water level.

Pioneer species most commonly observed in these secondary succession wet meadows included: Blue Vervain (*Verbena hastata*), Boneset (*Eupatorium perfoliatum*), Larger Canada St. John's Wort (*Hypericum majus*), Cursed Crowfoot (*Ranunculus sceleratus*), Northern Bugle Weed (*Lycopus uniflorus*), Panic Grass (*Dichanthelium sp.),* Silverweed (*Potentilla anserina*), Few-flowered Spike Rush (*Eleocharis quinqueflora*), Water Smartweed (*Persicaria amphibia*), and Yellow Cress (*Rorippa palustris*).

Due to Covid-19 U.S./Canada border restrictions, which resulted in a change of sampling areas and sites, one of our regular sampling regions, the Bruce Peninsula on Lake Huron, was surveyed several weeks earlier in the season than previous years' sampling schedule to that area. The earlier sampling time (mid-June) resulted in our finding several rare or uncommon species in peak bloom time, at two of our unique coastal sites, Sadler Creek Wetland 5 (5848), and Corisande Bay 5 (5206). Some of these rare or uncommon species surveyed included: Tall White Bog Orchid (*Platanthera dilatata*), Bulrush Sedge (*Carex scirpoidea*), Canada Bluets (*Houstonia canadensis*), Tufted Bulrush (*Trichophorum cespitosum*), Lesser Yellow Lady's Slipper (*Cypripedium parviflorum*), Seneca Snakeroot (*Polygala senega*), Green-Keeled Bog Cotton (*Eriophorum viridicarinatum),* and Butterwort (*Pinguicula vulgaris*). Selected voucher specimens were collected and added to the UWindsor reference collection.

Species at Risk:
<u>American Water Willow (*Justicia americana*)</u> COESWIC Status -Threatened: American Water Willow was observed for the second year in a row at one of our Lake Erie benchmark sites, Point Pelee Marsh 2 (5762). The same populations from 2020 were observed again in 2021. In

addition, Water Willow was surveyed in a new section of the marsh, which had not previously been sampled prior to 2021. In all instances, American Water Willow was observed on the outer edges of the floating cattail mats, and had a rather scattered, distribution, with only one or two individual plants surveyed in any given quadrat.

Swamp Rose Mallow (*Hibiscus moscheutos*) COESWIC Status – Special Concern: Swamp Rose Mallow was surveyed at two Lake Erie sites, Point Pelee Marsh 2 (5762) and Hillman Marsh (5422). This species had been observed at both locations prior to 2021. At both locations, it was found growing on the outer edges of the floating cattail mats or wet meadow, and in some surveyed quadrats, Swamp Rose Mallow accounted for over 50% of the total vegetation coverage of the sampling plot, likely due to the plant becoming rather large and dominating by late summer, which was the time of the year that both sites were sampled.

Vasey's Pondweed (*Potamogeton vaseyi*): Vasey's Pondweed is an uncommon Great Lakes species, and between 2020 and 2021, it was surveyed at a total of four of our northern Lake Huron sites which were all located within 11 km of one another, on or near the Canadian side of the St. Mary's River. These sites included: Findlay Point Wetland 1 (5280), Pumpkin Point 1 and 2 (5789 and 5790), and East Neebish Island (5264). While Vasey's Pondweed is currently not provincially or federally listed as a species at risk in Ontario or Canada, it is considered Threatened under the Endangered Species Act in the State of Michigan. Three of the four sites where Vasey's Pondweed was found were less than two km from the U.S/Michigan border. The observed records may reflect recent colonization by plants transported by high water from upstream populations in Lake Superior or from local inland lakes.

Invasive Species:
Water Lettuce (*Pistia stratiotes*): In 2021, invasive Water Lettuce was discovered for the first time by our vegetation crew at Turkey Creek (5999, Figure x). This site had been sampled three times in previous CWMP cycles, the last being in 2016, but it was not found during any of those years. This species was found growing in quiet, slow-moving areas of the creek, approximately 1 km inland from the creek mouth. Both scattered individual plants and small clustered populations were observed throughout the study area, and it was found in all three sampled transects.

Figure 31. Water Lettuce (*Pistia stratiotes*) found for the first time at Site 5999, Turkey Creek, Detroit River.

<u>Starry Stonewort (*Nitellopsis obtusa*):</u>
Starry Stonewort has continued its expansion in the Severn Sound section of Lake Huron. In 2021, it was found and surveyed in all three transects at Sturgeon Bay Complex (5965). This site had been sampled twice previously, the last year being 2016, and it was not observed at that time. Starry Stonewort was also observed again this year in Penetang Marsh 2 (5723), where it was first observed in 2020, and at Point Pelee Marsh 2 (5762).

Data Processing
All data have been compiled, are currently being entered into the databases, and are awaiting quality assurance checks.

Mid-season QC Check Findings
No difficulties or anomalies were observed during mid-season checks, which were self-administered, both due to COVID19-related travel restrictions and protocols and because field crew leaders have at least 5 years experience with the CWM teams.

Audit and QC Report and Findings

All data entry is routinely QC'd by an experienced CWM team member within a few days of original entry.

Additional Funding and Project Leverage Examples

In 2021, the Canadian Wildlife Service (CWS) initiated a multi-year wetland monitoring program (the Protected Areas Wetland Monitoring Program) for National Wildlife Areas (NWAs) that follows CWMP sampling protocols. These data can be compared to the basin-wide CWMP dataset to assess and track wetland condition in NWAs over time. This monitoring program will provide critical information necessary to effectively manage these important ecosystems and will be used to support current and future CWS priority projects and programs (e.g., ongoing *Phragmites* management monitoring at Big Creek and Long Point National Wildlife Areas).

Other Collaborations

Over the last two years, Point Pelee National Park (PPNP) has been sampled as part of the CWMP to provide Parks Canada 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. Sampling at PPNP is planned to continue post-restoration.

In 2020, vegetation CWMP data were used to establish criteria by which to delist several Beneficial Use Impairments in the Detroit River Area of Concern. Data from 2021 will be used to continue to refine these criteria.

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Other Data Requests

We occasionally receive requests for data from Canadian government agencies, which we refer to the project managers. The most recent request was from Environment and Climate Change Canada for vegetation data to support their Nearshore Framework assessment of Lake Erie habitat.

Related Student Research

One new PhD student, Pengfei Hou (2-year visiting PhD student from Yunnan University), is starting work this fall (2021) with Paul Weidman (supervisor at UWindsor, GLIER). Hou will be using remote sensing and spatial modeling approaches to analyze long-term variation in coastal wetland area and depth and water quality in nearshore regions of lakes Erie, Ontario, and Huron.

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US Eastern Basin Bird and Anuran Team at SUNY Brockport

Team Members

Dr. Kathryn Amatangelo, PI. Gregory Lawrence, project manager and field crew leader. Ray Marszalek and Robert Buckert, field technicians. Dr. Kathryn Amatangelo and Gregory Lawrence totaled two returning team members while Ray Marszalek and Robert Buckert totaled two new additions to the team in 2021.

Training

Both field technicians (R. Marszalek and R. Buckert) were trained by project manager and field crew lead Gregory Lawrence, who has been with on proper field sampling techniques, field work safety, bird and anuran identification and counting techniques, distance estimation, GPS use, and proper use of field equipment. Anuran training was held on April 18, 2021 at SUNY Brockport campus and at site 7052, Braddock Bay. Bird training was held on June 1, 2021 at SUNY Brockport campus and site 50, Cranberry Pond and site 7052, Braddock Bay. Both technicians were trained on July 26, 2021 for data entry and QC checks using the project database. Both field technicians successfully passed the bird and anuran identification tests, were successfully trained, and met pre-season training performance criteria described in the project QAPP.

Challenges and Lessons Learned

Loosened restrictions regarding the COVID-19 pandemic greatly reduced travel restrictions and logistical issues in 2021. However, the US-Canada border closure prevented our team from sampling any assigned sites in Canada.

Lake Ontario water levels returned from record highs in 2017 through 2019 to well below average in summer 2021 reducing standing water near the edges of the wetland, where bird and anuran sampling occur. Some sites required long walks to take water temperature (Figure

32) and this metric was not recorded at some points due to unsafe walks, especially during anuran surveys at night, through the wetland to find open water to take water temperatures.

Figure 32. Field technician R. Buckert walking out to sampling point.

Site Visit List

SUNY Brockport crews successfully sampled birds and anurans at 18 of the 25 assigned sites including 13 regular panel sites, two panel re-sample sites (site 95-Rice Creek, site 118-Salmon River), one panel pre-sample site (site 164-Guffin Bay), and two non-panel benchmark sites (site 7052-Braddock Bay, site 50-Cranberry Pond). Sites 164, Guffin Bay, 124, Blind Creek, 92, Eighteenmile Creek, 130, Black Pond, and 197, Mud Bay Marsh 1 were not sampled due to lack of access through private land. In these cases, landowners were either not willing to allow access or did not respond to in person and/or phone inquiries. Lastly, site 7051, South Pond Wetland 2, was not sampled due to the wetland not meeting sampling criteria as a coastal wetland due to absence of open water, dominance of forest and woody vegetation, and no direct connection to Lake Ontario or its tributaries.

Site 7052, Braddock Bay, was sampled for birds and anurans as a non-panel benchmark site to supplement continued post-restoration monitoring of a Great Lakes Restoration Initiative-funded project in conjunction with partners at the New York State Department of Environmental Conservation, US Army Corps of Engineers, and the Town of Greece, NY.

Site 50, Cranberry Pond, was sampled for birds and anurans as a non-panel benchmark site to supplement continued post-restoration monitoring of a National Fish and Wildlife Foundation-funded project in conjunction with partners at the New York State Department of Environmental Conservation, Ducks Unlimited, National Audubon Society, and Audubon New York.

Panel Survey Results

SUNY Brockport crews sampled anurans starting on April 28, 2021 and finished sampling on July 5, 2021. Crews detected six anuran species, including spring peeper (*Pseudacris crucifer*), gray tree frog (*Hyla versicolor*) northern leopard frog (*Lithobates pipiens*), green frog (*Lithobates clamitans*), bullfrog (*Lithobates catesbeiana*), and American toad (*Anaxyrus americanus*). Crews did not detect wood frog (*Lithobates sylvaticus*), likely due to the species' brief and early burst of vocalizations shortly after the first warm day of the season. More notably, crews failed to detect chorus frogs (*Pseudacris triseriata*) this year, despite the species presence at many of the same sites during past sampling years.

SUNY Brockport crews sampled birds starting on June 1, 2021 and finished sampling on July 5, 2021. Crews detected three species listed as threatened in New York State including Pied-billed Grebe (*Podilymbus podiceps*) at site 118, Salmon River and Least Bittern (*Ixobrychus exilis*) at site 76, Red Creek, and 7027, East Sodus/Leroy Island, and Common Tern (*Sterna hirundo*) at site 1938, Beaver Island. Crews detected Osprey (*Pandion haliaetus*), listed as a species of special concern in New York State, at sites 10: Johnson Creek; 27: Payne Beach; 62: Maxwell Bay; 66: East Bay; 133: Stony Creek; 163: Perch River; 186: Long Carry Marsh; 187: Fox Creek; 7052: Braddock Bay; and 7027: East Sodus/Leroy Island. Crews failed to detect Black Tern (*Chlidonias niger*), listed as an endangered species in New York State, at any sites during summer 2021, despite this species being present during sampling at the same sites in past years.

Extra Sites and Data

Site 7052, Braddock Bay, was sampled for birds and anurans as a non-panel benchmark site to supplement continued post-restoration monitoring of a Great Lakes Restoration Initiative-funded project in conjunction with partners at the New York State Department of Environmental Conservation, US Army Corps of Engineers, and the Town of Greece, NY. Site 50, Cranberry Pond, was sampled for birds and anurans as a non-panel benchmark site to supplement continued post-restoration monitoring of a National Fish and Wildlife Foundation-funded project in conjunction with partners at the New York State Department of Environmental Conservation, Ducks Unlimited, National Audubon Society, and Audubon New York. Least Bittern, listed as a threatened species in New York State, was not detected at these sites during surveys, but was heard during anuran sampling at site 50, Cranberry Pond. Bald Eagle, also listed as a threatened species in New York State was detected at site 7052, Braddock Bay and Osprey, listed as a species of special concern in New York State, was detected at both site 7052, Braddock Bay, and 50, Cranberry Pond.

Figure 33. Green Frog (*Lithobates clamitans*) at site 7052, Braddock Bay.

Data collected at these sites will help inform stakeholders, partners, and land managers on post-restoration wetland conditions and will help guide adaptive management actions. All data from these benchmark sites were included in the data management system as these sites are panel sites too and data collection followed all protocols in this project's SOP and QAPP.

Wetland Condition Observations and Results

Water levels on Lake Ontario were well below average in summer 2021 resulting in little water near the edges of the wetland, where bird and anuran surveys occur. This could possibly impact detectability of secretive marsh birds and focal species, who require some interspersion of water and vegetation. We did not detect any other significant disturbances across the sites in the US Eastern basin on birds and anurans.

Data Processing

SUNY Brockport crews have completed 100% data entry and QC checks for bird and anuran data and the dual entry process is complete with all issues resolved.

Mid-season QC Check Findings

The bird and anuran mid-season QC check was completed on July 1, 2021 at sites 29, Long Pond, 50, Cranberry Pond, and 7052, Braddock Bay. Both crew members (R. Marszalek and R. Buckert) successfully met mid-season check performance criteria described in the project QAPP and had no issues requiring corrective action

Audit and QC Report and Findings

SUNY Brockport crews have completed 100% data entry and QC checks for bird and anuran data and the dual entry process is complete with all issues resolved. Data review by project manager Gregory Lawrence found no issues and thus, no corrective actions were required.

Additional Funding and Projects

No additional funding was used for any related projects or additional sampling.

Other Collaboration Activities

Site 7052, Braddock Bay, was sampled for birds and anurans as a non-panel benchmark site to supplement continued post-restoration monitoring of a Great Lakes Restoration Initiative-funded project in conjunction with partners at the New York State Department of Environmental Conservation, US Army Corps of Engineers, and the Town of Greece, NY. Site 50, Cranberry Pond, was sampled for birds and anurans as a non-panel benchmark site to supplement continued post-restoration monitoring of a National Fish and Wildlife Foundation-funded project in conjunction with partners at the New York State Department of Environmental Conservation, Ducks Unlimited, National Audubon Society, and Audubon New York.

Figure 34. Common Yellowthroat (*Geothlypis trichas*) at site 133, Stony Creek.

Bird survey data from all sites in New York State were included in the Third New York State Breeding Bird Atlas to help supplement efforts aiming to determine the current distribution and occupancy of breeding birds in New York State. This project is in collaboration with partners at New York Natural Heritage Program, New York State Department of Environmental Conservation, Audubon New York, Cornell Lab or Ornithology, and New York State Ornithological Association.

Further, SUNY Brockport crews shared state listed fish species found at site 10, Johnson Creek, and 1938, Beaver Island, with partners at New York State Office of Parks Recreation and Historic Preservation, who manage most of the surrounding property as Lakeside Beach State Park and Beaver Island State Park.

US Eastern Basin Fish, Invertebrate, and Water Quality Team at SUNY Brockport

Team Members

Dr. Kathryn Amatangelo, Dr. Matthew Altenritter, and Dr. Michael Chislock, PIs. Gregory Lawrence, Project Manager. Kylee Wilson, field crew lead. Matthew Beers, Jacob Bensley, and Kaitlyn Stowell, summer field technicians. All three PIs, project manager, field crew lead, and one field technician (J. Bensley) total six returning team members. Two field technicians (M. Beers, K. Stowell) were new additions to the team in 2021.

Training

All four field technicians (including the field crew lead) were trained by PIs Dr. Kathryn Amatangelo, Dr. Michael Chislock, Dr. Matthew Altenritter and project manager Gregory Lawrence on proper field sampling techniques, lab data collection and recording, GPS use, boat use and safety. Invertebrate and water quality team members were trained by PIs Dr. Michael Chislock and Dr. Kathryn Amatangelo and project manager Gregory Lawrence on proper water quality sample storage, processing, and analysis, and proper invertebrate sample processing and storage. Both fish team members were trained by Dr. Matthew Altenritter on fish identification and sample preservation and storage. All training took place June 21-25, 2021 at the SUNY Brockport campus, Glenwood Lake reservoir in Medina, NY for boat training, and at Long Pond (site 29) for field training. Lastly, all four field technicians were trained on August 3, 2021 on data entry and QC checks in the database. All four field technicians were successfully trained and met pre-season training performance criteria described in the project QAPP.

Challenges and Lessons Learned

Loosened restrictions regarding the COVID-19 pandemic greatly reduced travel restrictions and logistical issues in 2021. However, the US-Canada border closure prevented our team from sampling any assigned sites in Canada.

Lake Ontario water levels returned from record highs in 2017 and 2019 to well below average in summer 2021. This allowed for easier fish sampling in vegetation zones with proper water depth, though caused some boat launches to be difficult to navigate.

Site Visit List

The SUNY Brockport team successfully sampled water quality and invertebrates at 20 of the 23 assigned sites including 16 regular panel sites, two panel re-sample sites (site 95-Rice Creek, site 118-Salmon River), two panel pre-sample sites (site 1863-Hemming Ditch, site 164-Guffin Bay), and three non-panel benchmark sites (site 7052-Braddock Bay, site 50-Cranberry Pond, site 133-Stony Creek). The SUNY Brockport team successfully sampled fish at 17 of the 23 assigned sites. Site 95, Rice Creek; site 50, Cranberry Pond; and site 23, East Creek were not sampled for fish due to lack of appropriate vegetation zones and water depth needed to safely set fyke nets. Site 92, Eighteenmile Creek, and site 130, Black Pond were not sampled for fish, water quality, and invertebrates due to lack of access to the sites on private land. Site 7051, South Pond Wetland 2, was not sampled due to the wetland not meeting sampling criteria as a coastal wetland due to absence of open water, dominance of forest and woody vegetation, and no direct connection to Lake Ontario or its tributaries.

Site 7052, Braddock Bay, was sampled for fish, water quality, and invertebrates as a non-panel benchmark site to supplement continued post-restoration monitoring of a Great Lakes Restoration Initiative-funded project in conjunction with partners at the New York State Department of Environmental Conservation, US Army Corps of Engineers, and the Town of Greece, NY. Site 50, Cranberry Pond, was sampled for water quality and invertebrates as a non-panel benchmark site to supplement continued post-restoration monitoring of a National Fish and Wildlife Foundation-funded project in conjunction with partners at the New York State Department of Environmental Conservation, Ducks Unlimited, National Audubon Society, and Audubon New York. We did not sample fish at this site due to lack of appropriate vegetation zones and water depths for safely setting fyke nets. Site 133, Stony Creek, was sampled for fish, water quality, and invertebrates as a non-panel benchmark site as bird and anuran index of ecological condition values indicated it was a high quality site and it had never been sampled for fish, invertebrates, plants, and water quality due to exceeding site capacity. Site 133 was added as a benchmark for fish, water quality, and invertebrates in order to better sample sites with extremely good or poor environmental condition, as well as to better assess the overall site condition by sampling all taxa.

Panel Survey Results

SUNY Brockport crews sampled fish, water quality, and invertebrates at panel sites starting on June 28, 2021 at site 7052, Braddock Bay, and finished on August 2, 2021 at site 1866, Bay View wetland. Crews caught and identified 30 fish taxa and four reptile taxa across the 17 sites sampled. Crews even caught an immature Wood Duck (*Aix sponsa*) in a net at site 1866, Bay View wetland, that was brought to a nearby wildlife rehabilitator who notified us later that the bird was successfully nursed back to health and released.

Notable fish included longnose gar (*Lepisosteus osseus*) at sites 1859, Plum Brook Area Wetland 2, site 1862, Plum Brook Area Wetland 3, site 1866, Bay View wetland, and site 186, Long Carry Marsh (Figure 35). Crews also caught numerous bowfin (*Amia calva*) and spotted sucker (*Minytrema melanops*) at sites 1859, Plum Brook Area Wetland 2, and 1862, Plum Brook Area Wetland 3. Crews noted multiple invasive species including goldfish (*Carassius auratus*) at site 16, Sandy Creek; site 29, Long Pond; site 1859, Plum Brook Area Wetland 2; site 1862, Plum

Brook Area Wetland 3, and site 1866, Bay View wetland. Crews caught invasive common carp (*Cyprinus carpio*) at sites 62, Maxwell Bay; 118, Salmon River; 163, Perch River; 164, Guffin Bay; 186, Long Carry Marsh; 1859, Plum Brook Area Wetland 2; 1862, Plum Brook Area Wetland 3; 1863, Hemming Ditch, and 1866, Bay View wetland. Crews caught invasive round goby (*Neogobius melanostomus*) at sites 16, Sandy Creek; 10, Johnson Creek; 163, Perch River; 186, Long Carry Marsh, and 187, Fox Creek. Crews also caught invasive tubenose goby (*Proterorhinus semilunaris*) at site 187, Fox Creek.

Figure 35. Longnose gar (*Lepisosteus osseus*) exceeding the length of the measuring board at site 186, Long Carry Marsh.

Reptiles included common snapping turtles (*Chelydra serpentina*) and painted turtles (*Chrysemys picta*) at numerous sites. Crews caught musk turtles (*Sternotherus odoratus*), listed as a high priority species of greatest conservation need in New York State, at site 29, Long Pond; site 66, East Bay, and site 133, Stony Creek, where they caught seven in the submerged aquatic vegetation zone. Lastly, crews caught map turtles (*Graptemys geographica*) at site 62, Maxwell Bay, and site 1859, Plum Brook Area Wetland 2.

Extra Sites and Data

Site 7052, Braddock Bay, was sampled for fish, water quality, and invertebrates as a non-panel benchmark site to supplement continued post-restoration monitoring of a Great Lakes Restoration Initiative-funded project in conjunction with partners at the New York State Department of Environmental Conservation, US Army Corps of Engineers, and the Town of Greece, NY. Crews caught a painted turtle here and eight fish taxa including four large bowfin. Site 50, Cranberry Pond, was sampled for water quality and invertebrates as a non-panel benchmark site to supplement continued post-restoration monitoring of a National Fish and Wildlife Foundation-funded project in conjunction with partners at the New York State

Department of Environmental Conservation, Ducks Unlimited, National Audubon Society, and Audubon New York. We did not sample fish at this site due to lack of appropriate vegetation zones and water depths for safely setting fyke nets. Site 133, Stony Creek, was sampled for fish, water quality, and invertebrates as a non-panel benchmark site as bird and anuran index of ecological condition values indicated it was a high quality site and it had never been sampled for fish, invertebrates, plants, and water quality due to exceeding site capacity. Site 133 was added as a benchmark in order to better sample sites with extremely good or poor environmental condition, as well as to better assess the overall site condition by sampling all taxa. Crews caught nine fish taxa here including bowfin and a northern pike (*Esox lucius*). Crews also caught two reptile species including three painted turtles and seven musk turtles, noted as a high priority species of greatest conservation need in New York State.

Data collected at these sites will help inform stakeholders, partners, and land managers on post-restoration wetland conditions and will help guide adaptive management actions. All data from these benchmark sites were included in the data management system as these sites are panel sites too and data collection followed all protocols in this project's SOP and QAPP.

Wetland Condition Observations and Results

Water levels on Lake Ontario were well below average in summer 2021 resulting in sometimes difficult site access at some boat launches. Further, low lake levels in many Lake Ontario sites, particularly in those with lily zones, likely contributed to low dissolved oxygen levels and thus lower concentrations of invertebrates. However, the low lake levels allowed for appropriate water depths in multiple vegetation zones that have been too deep to safely and adequately sample in recent years.

Data Processing

SUNY Brockport crews have completed 100% data entry and QC checks for fish, field water quality, and field invertebrate data. 100% of unknown fish were identified and entered in the database. 100% of laboratory water quality analyses, data entry, and QC checks were completed. 25% of laboratory invertebrate processing and identification was completed and is on target to be completed later in winter 2021-22.

Mid-season QC Check Findings

The water quality and invertebrate mid-season QC check was completed on July 16, 2021 at site 124, Blind Creek, and site 133, Stony Creek by Dr. Michael Chislock and project manager Gregory Lawrence. Both crew members (J. Bensley and K. Stowell) successfully met mid-season check performance criteria described in the project QAPP and had no issues requiring corrective action. The fish mid-season QC check was completed on July 14, 2021 at site 118, Salmon River, by Dr. Matthew Altenritter. Both crew members (K. Wilson and M. Beers) successfully met mid-season performance criteria described in the project QAPP and had no issues requiring corrective action.

Audit and QC Report and Findings

SUNY Brockport crews have completed 100% data entry QC checks for fish, field water quality, and field invertebrate data. 100% laboratory water quality analyses, data entry, and QC checks were completed.

Additional Funding and Projects

No additional funding was used for any related projects or additional sampling.

Other Collaboration Activities

Site 7052, Braddock Bay, was sampled for fish, water quality, and invertebrates as a non-panel benchmark site to supplement continued post-restoration monitoring of a Great Lakes Restoration Initiative-funded project in conjunction with partners at the New York State Department of Environmental Conservation, US Army Corps of Engineers, and the Town of Greece, NY. Site 50, Cranberry Pond, was sampled for water quality and invertebrates as a non-panel benchmark site to supplement continued post-restoration monitoring of a National Fish and Wildlife Foundation-funded project in conjunction with partners at the New York State Department of Environmental Conservation, Ducks Unlimited, National Audubon Society, and Audubon New York. Further, SUNY Brockport crews collaborated with Finger Lakes and St. Lawrence-Eastern Lake Ontario Partnerships for Regional Invasive Species Management by reporting invasive species, such as round and tubenose goby, detected at each wetland. Finally, SUNY Brockport crews shared state listed fish species found at site 10, Johnson Creek, with partners at New York State Office of Parks Recreation and Historic Preservation, who manage most of the surrounding property as Lakeside Beach State Park.

US Eastern Basin Vegetation Team at SUNY Brockport

Team Members

Dr. Kathryn Amatangelo, Dr. Rachel Schultz, PIs. Gregory Lawrence, project manager. Kevin Killigrew and Sky Symonds, field technicians. Both PIs, the project manager, and one field technician (K. Killigrew) total four returning team members, while one field technician (S. Symonds) was a new addition to the team in 2021.

Training

Both field technicians (K. Killigrew, S. Symonds) were trained by PIs Dr. Kathryn Amatangelo, Dr. Rachel Schultz, and project manager Gregory Lawrence on proper field sampling techniques, data collection and recording, GPS use, and boat use and safety. Both plant team members were trained by Dr. Rachel Schultz on plant identification and sample preservation and storage. All training took place June 21-25, 2021 at the SUNY Brockport campus, Glenwood Lake reservoir in Medina, NY for boat training, and at site 29, Long Pond, for field training. Lastly, both field technicians were trained on August 3, 2021 on data entry and QC checks in the database. Both field technicians were successfully trained, passed the plant identification quiz, and met pre-season training performance criteria described in the project QAPP.

Challenges and Lessons Learned

Loosened restrictions regarding the COVID-19 pandemic greatly reduced travel restrictions and logistical issues in 2021. However, the US-Canada border closure prevented our team from sampling any assigned sites in Canada.

Lake Ontario water levels returned from record highs in 2017 and 2019 to well below average in summer 2021. This caused some boat launches to be difficult to navigate.

Site Visit List

The SUNY Brockport team successfully sampled vegetation at 20 of the 23 assigned sites including 16 regular panel sites, two panel re-sample sites (site 95-Rice Creek, site 118-Salmon River), two panel pre-sample sites (site 1863-Hemming Ditch, site 164-Guffin Bay), and three non-panel benchmark sites (site 7052-Braddock Bay, site 50-Cranberry Pond, site 133-Stony Creek). Site 92, Eighteenmile Creek, and site 130, Black Pond, were not sampled for vegetation due to lack of access to the sites on private land. Site 7051, South Pond Wetland 2, was not sampled due to the wetland not meeting sampling criteria as a coastal wetland due to absence of open water, dominance of forest and woody vegetation, and no direct connection to Lake Ontario or its tributaries.

Site 7052, Braddock Bay, was sampled for vegetation as a non-panel benchmark site to supplement continued post-restoration monitoring of a Great Lakes Restoration Initiative-funded project in conjunction with partners at the New York State Department of Environmental Conservation, US Army Corps of Engineers, and the Town of Greece, NY. Site 50, Cranberry Pond, was sampled for vegetation as a non-panel benchmark site to supplement continued post-restoration monitoring of a National Fish and Wildlife Foundation-funded project in conjunction with partners at the New York State Department of Environmental Conservation, Ducks Unlimited, National Audubon Society, and Audubon New York. Site 133, Stony Creek, was sampled for vegetation as a non-panel benchmark site as bird and anuran index of ecological condition values indicated it was a high quality site and it had never been sampled for vegetation due to exceeding site capacity. Site 133 was added as a benchmark for vegetation in order to better sample sites with extremely good or poor environmental condition, as well as to better assess the overall site condition by sampling all taxa.

Panel Survey Results

SUNY Brockport crews sampled vegetation at panel sites starting on June 28, 2021 at site 7052, Braddock Bay, and finished on August 2, 2021 at site 1866, Bay View wetland. Crews noted seeing wild rice (*Zizania* sp.) at site 163, Perch River, and large patches in the emergent zone at site 187, Fox Creek (Figure 36). Crews noted more sedge-grass meadow zones than they usually see, with most dominated by sedges and grasses rather than invading cattail. Crews noted high percent covers of cattail (*Typha angustifolia*, *Typha* x *glauca*), *Phragmites australis, Lythrum salicaria,* and *Hydrocharis morsus-ranae* at most sites. Many of these invasive species dominated the vegetation community at most sites on Lake Ontario. Further, crews noted invasive water chestnut (*Trapa natans*) at sites 29, Long Pond; 62, Maxwell Bay; 66, East Bay; and 95, Rice Creek. Lastly, crews noted vast patches of American lotus (*Nelumbo lutea*) at Lake Erie sites 1859, Plum Brook Wetland 2; 1862, Plum Brook Wetland 3; 1863, Hemming Ditch, and 1866, Bay View Wetland (Figure 37).

Figure 36. Wild rice (*Zizania* sp.) at site 187, Fox Creek.

Extra Sites and Data

Site 7052, Braddock Bay, was sampled for vegetation as a non-panel benchmark site to supplement continued post-restoration monitoring of a Great Lakes Restoration Initiative-funded project in conjunction with partners at the New York State Department of Environmental Conservation, US Army Corps of Engineers, and the Town of Greece, NY. This site was dominated by invasive *Typha* sp., and had high concentrations of invasive *Lythrum salicaria* and *Hydrocharis morsus-ranae*. Site 50, Cranberry Pond, was sampled for vegetation as a non-panel benchmark site to supplement continued post-restoration monitoring of a National Fish and Wildlife Foundation-funded project in conjunction with partners at the New York State Department of Environmental Conservation, Ducks Unlimited, National Audubon Society, and Audubon New York. This site includes a rare coastal fen and crews detected unique species such as *Drosera rotundifolia, Vaccinium macrocarpon*, and *Sphagnum* sp. Site 133, Stony Creek, was sampled for vegetation as a non-panel benchmark site because bird and anuran index of ecological condition values indicated it was a high quality site and it had never been sampled for fish, invertebrates, plants, and water quality due to exceeding site capacity. Site 133 was added as a benchmark in order to better sample sites with extremely good or poor environmental condition, as well as to better assess the overall site condition by sampling all taxa. This site had very diverse vegetation with one transect even reaching 40 taxa.

Figure 37. American lotus (*Nelumbo lutea*) at site 1863, Hemming Ditch.

Data collected at these sites will help inform stakeholders, partners, and land managers on post-restoration wetland conditions and will help guide adaptive management actions. All data from these benchmark sites were included in the data management system because these sites are panel sites too, and data collection followed all protocols in this project's SOP and QAPP.

Wetland Condition Observations and Results

Water levels on Lake Ontario were well below average in summer 2021 resulting in sometimes difficult site access at some boat launches. Crews noted an increase in dead *Typha* cover and decrease in live *Typha* cover in sedge-grass meadow zones in summer 2021. Live *Typha* was more sparse, shorter, and had fewer inflorescences than the adjacent dead *Typha*. This suggested the lower lake levels starting in Fall 2020 may have facilitated growth of sedges and grasses and impeded *Typha* growth in the sedge-grass meadow zones.

Data Processing

SUNY Brockport crews have completed 100% data entry and QC checks for vegetation data. 100% unknown plants were identified and entered in the database.

Mid-season QC Check Findings

The vegetation mid-season QC check was completed on July 13, 2021 at site 66, East Bay by Dr. Rachel Schultz. Both crew members (K. Killigrew and S. Symonds) successfully met mid-season check performance criteria described in the project QAPP and had no issues requiring corrective action.

Audit and QC Report and Findings

SUNY Brockport crews have completed 100% data entry and QC checks for vegetation data. 100% unknown plants were identified and entered in the database.

Additional Funding and Projects

No additional funding was used for any related projects or additional sampling.

Other Collaboration Activities

Site 7052, Braddock Bay, was sampled for vegetation as a non-panel benchmark site to supplement continued post-restoration monitoring of a Great Lakes Restoration Initiative-funded project in conjunction with partners at the New York State Department of Environmental Conservation, US Army Corps of Engineers, and the Town of Greece, NY. Site 50, Cranberry Pond, was sampled for vegetation as a non-panel benchmark site to supplement continued post-restoration monitoring of a National Fish and Wildlife Foundation-funded project in conjunction with partners at the New York State Department of Environmental Conservation, Ducks Unlimited, National Audubon Society, and Audubon New York. Further, SUNY Brockport crews collaborated with partners at the New York State Department of Environmental Conservation, Genesee Valley Audubon Society, and Finger Lakes and St. Lawrence-Eastern Lake Ontario Partnerships for Regional Invasive Species Management by reporting invasive species, such as *Trapa natans* and *Nitellopsis obtusa*, detected at each wetland.

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. Project PIs signed the updated QAPP (QAPP_CWMII_v1) at the February 19, 2016 meeting. In thoroughly reviewing the QAPP and SOPs in early 2018, crews found inconsistencies between the QAPP and SOPs and another handful of minor corrections and clarifications. 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.

For the third 5-year sampling rotation, again no substantial methodological or QA/QC changes were necessary. The QAPP was updated to reflect turnover in program personnel, to continue to strive for clarity and understandability by others and to make the QAPP more of a stand-alone document without reference to proposals or reports, and to remove inconsistencies between the QAPP and SOPs. The only substantive change was to update the water chemistry section to better reflect the updated EPA guidance on calculating error and variability in various water chemistry measurements. This QAPP (QAPP_CWMPIII_2021) was signed by PIs in the spring of 2021

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

- 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 sent their new staff to the closest collaborating lab for training Macroinvertebrate IDers communicate with each other via their own email list and assist each other with difficult identifications and other questions that arise.

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

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

- Review of sites rejected after initial site visits: In cases where a site was rejected during a site visit, the reason for rejection was documented by the field crew in the site selection database. The project QA managers (Brady and Cooper) then reviewed these records to ensure consistency among crews. Occasionally, field crew leaders contacted Uzarski, Brady, or Cooper 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, but had returned to normal by 2020 as crews have become more accustomed to the high water levels and because water levels dropped quite a bit in 2021 with drought across the upper Great Lakes.

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

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

- Collection of duplicate field samples: Precision and accuracy of many field-collected variables is being evaluated with duplicate samples. Duplicate water quality samples were collected at approximately every 10th WQ sample collected.

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

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

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

- Creation/maintenance of specimen reference collections: Reference collections for macroinvertebrates, fish, and plants have either been created or are being maintained and updated by each regional team. Macroinvertebrate reference collections, in particular, were developed or expanded as these samples were processed. 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.

Data verification

Over the past year significant progress has been made toward the design and implementation of a data verification protocol that can be used to identify and resolve, or otherwise flag, issues related to data accuracy, consistency, and compliance with the Quality Assurance Project Plan (QAPP) and SOPs established for sampling the various taxa groups. The overall goal of this process is to establish the *usability* of each data record to ensure that the CWMP datasets are properly communicated to and applied by end data users. Initially, approximately 120 data verification criteria (rules) were developed by GDIT (USEPA's contractor) to conduct a suite of checks for specific components of the anuran, bird, vegetation, fish, macroinvertebrate, and water quality datasets. Examples of data verification checks include:

- Identifying bird surveys that took place outside the sampling seasonal frame (e.g., after breeding season).
- Identifying fish surveys for which 2 nets did not fish correctly and yet the crew entered data from those nets.
- Identifying vegetation surveys with less than three transects sampled.

The data verification checks have been automated by GDIT to run against the semi-annual release CWMP database (MS Access format) that delivered to GLNPO in April and October of each year. Each record that fails to meet specific verification criteria (such as they listed above) is flagged with an appropriate *data qualifier code* (e.g., "LINTC" – lack of internal consistency, or "MRV" – missing required value). The results from the automated checks are written to a set of comma-separated variable (CSV) files (i.e., one file per check type), which are delivered by GDIT to LimnoTech for integration into the CWMP DMS. Over the past six months, LimnoTech has incorporated additional tables (“data_rev_*”) into the DMS and developed a utility application to ingest the CSV files into those dedicated tables. The enhanced DMS provides the capability to store and manage multiple sets of data verification results, including tracking of issue resolution and the assignment of data usability flags on a record-specific basis. Verification check results are stored in a set of dedicated tables, which are readily linked to any CWMP taxa data table that the results may be associated with. While this approach supports linking the raw data to verification results/flags when needed, it also avoids burdening the raw data tables with the detailed verification information.

Due to the large variety and number of verification checks and results, a dedicated [“Data Verification” page] was implemented by LimnoTech on the CWMP main website to provide a platform for CWMP team members to efficient review and respond to individual verification results (Figure 38). The tool will allow any “Level 4” CWMP user to efficiently filter for verification results that are pertinent to their specific taxa team, to download the results to an Excel spreadsheet, and then to provide appropriate feedback for each individual result, including documenting the resolution of the issue (if any). Ultimately, each record will be assigned an appropriate data usability flag, although the specific approach for this is still under discussion at this time.

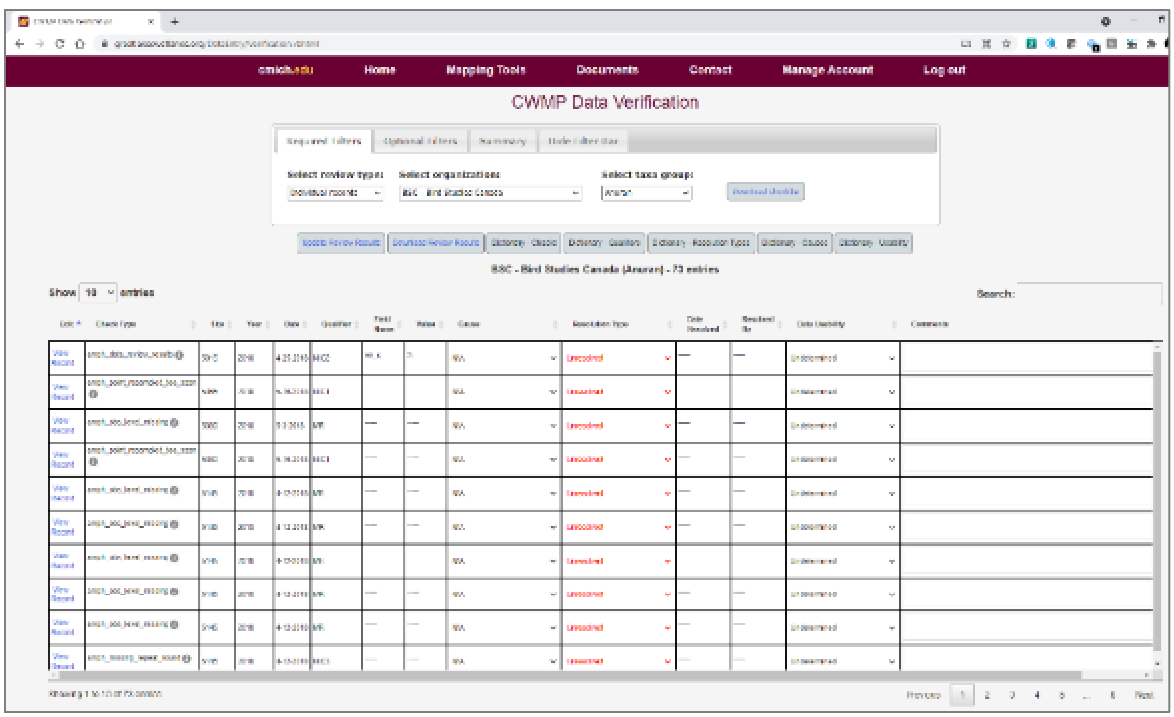

Figure 38. CWMP data verification user interface.

The CWMP lead PIs are currently reviewing verification criteria information provided by GLNPO and GDIT, as well as the data verification tool described above, to critically review and then suggest modifications to the draft verification rules. Based on that feedback, it is anticipated that the official set of verification checks will be revised and a new set of check results will be generated and incorporated into the CWMP DMS. After that process has been completed, roll-out and training for the data verification tool will be provided to all CWMP team members involved with data entry and quality review. The roll-out effort is currently anticipated to occur prior to the start of the 2022 CWMP field season.

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 the two most recent project years is shown in Table 20. The table was not 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 will be updated for the spring 2021 report. It is important to note that for many constituents, the variability within sample sets is related to the mean concentration, and as concentrations approach the method detection limit (MDL), the variability increases dramatically. A calculation of field replicate variability with values at or near the level of detection will often result in high RPDs. For example, if the chlorophyll measurements on a set of field duplicates are 0.8 µg/L and 0.3 µg/L, mean = 0.6, resulting in a RPD of 91% (RPD = [abs (rep a-rep b)/ (rep a+ rep b)/2)]*100, but since the MDL is ± 0.5 µg/L, this can be misleading.

The same can occur with analyte lab duplicates, and in these instances the QA officer will determine whether data are acceptable. It is also important to note that RPD on field duplicates incorporates environmental (e.g., spatial) variability, since duplicate samples are collected from adjacent locations, as well as analytical variability (e.g., instrument drift). Therefore, RPD of field duplicates is generally higher than RPD of laboratory duplicates. Table 21 below lists average RPD values for each year of round 2 of this sampling program (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 eleventh year (first year of round 3 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 for 2020 and to some extent for 2021, depending on the field crew and PI, depending on Covid-19 guidance from states and universities and vaccination status of PIs and field crews. However, again this year most crews had returning and experienced personal and the PIs were able to do training either in person or virtually 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 project has been fully implemented and PIs and their respective staff members continue to follow established protocols very closely, relying on the QAPP and SOPs as guiding documents. QA managers were also encouraged by each crew's continued willingness to contact their supervisors or, in many cases, the project management team when questions arise.

Despite the somewhat dangerous nature of this work, injury rates continue to be very low. We are very proud of what our field crews accomplished safely the past two years 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
- Evaluating fish assemblage changes throughout the summer in St. Marys River coastal wetlands (Lake Superior State University)
- Quantifying litter decomposition in wetlands of varying condition (Lake Superior State University)

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 or 2021 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.

Hirsch, B. E.E. Gnass Giese, and R. Howe. 2021. Anuran Occurrences in High and Low Water within the Lower Green Bay & Fox River AOC. Wisconsin Wetlands Association Conference, Virtual. Poster Presentation. February 2021.

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

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

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

Howe, R.W., R.P. Axler, V.J. Brady, T.N. Brown, J.J.H. Ciborowski, N.P. Danz, J.P. Gathman, G.E. Host, L.B. Johnson, K.E. Kovalenko, G.J. Niemi, and E.D. Reavie. 2012. Multi-species indicators of ecological condition in the coastal zone of the Laurentian Great Lakes. 97th Annual Meeting of the Ecological Society of America. Portland, OR.

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

Howe, R.W., G.J. Niemi, N.G. Walton, E.E.G. Giese, A.M. Bracey, V.J. Brady, T.N. Brown, J.J.H. Ciborowski, N.P. Danz, J.P. Gathman, G.E. Host, L.B. Johnson, K.E. Kovalenko, and E.D. Reavie. 2014. Measurable Responses of Great Lakes Coastal Wetland Biota to Environmental Stressors. International Association for Great Lakes Research Annual Conference, Hamilton, Ontario (Canada). May 26-30, 2014. Oral Presentation.

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

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

Howe, R.W., A.T. Wolf, and E.E. Gnass Giese. 2016. What's so special about Green Bay wetlands? Wisconsin Wetlands Association Conference, Radisson Hotel & Convention Center, Green Bay, Wisconsin. February 23-25, 2016. Oral Presentation.

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

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

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

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

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

Johnson, L., M. Cai, D. Allan, N. Danz, D. Uzarski. 2015. Use and interpretation of human disturbance gradients for condition assessment in Great Lakes coastal ecosystems. International Association for Great Lakes Research Conference, Burlington, VT.

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

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

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

Kosiara, J.M., M.J. Cooper, D.G. Uzarski, and G.A. Lamberti. 2013. Relationships between community metabolism and fish production in Great Lakes coastal wetlands. International Association for Great Lakes Research, 56th annual meeting. June 2-6, 2013. West Lafayette, IN. Poster presentation.

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

Kneisel, A.K., M.J. Cooper, D.G. Uzarski. 2018. Coastal wetland monitoring data as a resource for invasive species management. ELLS-IAGLR Big Lakes Small World Conference. Évian, France. September. Poster.Kosiara, J.K., J.J. Student, and D.G. Uzarski. 2017. Exploring coastal habitat-use patterns of Great Lakes yellow perch with otolith microchemistry. 60th International Conference on Great Lakes Research, Detroit, MI. May. Presentation.

Kosiara, J.M., J. Student and D.G. Uzarski. 2016. Assessment of yellow perch movement between coastal wetland and nearshore waters of the Great Lakes. 59th International Conference on Great Lakes Research, Guelph, Ontario Canada. May. Oral Presentation.

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

Lamberti, G.A., D.G. Uzarski, V.J. Brady, M.J. Cooper, T.N. Brown, L.B. Johnson, J.J. Ciborowski, G.P. Grabas, D.A. Wilcox, R.W. Howe, and D. C. Tozer. An integrated monitoring program for Great Lakes coastal wetlands. Society for Freshwater Science Annual Meeting. Jacksonville, FL. May 2013. Poster presentation.

Lamberti, G.A. Pacific Salmon in Natal Alaska and Introduced Great Lakes Ecosystems: The Good, the Bad, and the Ugly. Department of Biology, Brigham Young University. Dec 5, 2013. Invited seminar.

Lamberti, G. A. The Global Freshwater Crisis. The Richard Stockton College of New Jersey and South Jersey Notre Dame Club. November 18, 2014.

Lamberti, G. A. The Global Freshwater Crisis. Smithsonian Journey Group and several University Alumni Groups. March 1, 2015.

Lamberti, G.A. The Global Freshwater Crisis. Newman University and Notre Dame Alumni Club of Wichita. September 28, 2016.

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

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

Lamberti, G. A. Pacific Salmon in Natal Alaska and Introduced Great Lakes Ecosystems: The Good, the Bad, and the Ugly. Annis Water Resources Institute, Grand Valley State University. December 12, 2014.

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

Langer, T.A., K. Pangle, B.A. Murray, and D.G. Uzarski. 2014. Beta Diversity of Great Lakes Coastal Wetland Communities: Spatiotemporal Structuring of Fish and Macroinvertebrate Assemblages. American Fisheries Society, Holland, MI. February.

Langer, T., K. Pangle, B. Murray, D. Uzarski. 2013. Spatiotemporal influences, diversity patterns and mechanisms structuring Great Lakes coastal wetland fish assemblages. Poster. Institute for Great Lakes Research 1st Symposium, MI. March.

Lemein, T.J., D.A. Albert, D.A. Wilcox, B.M. Mudrzynski, J. Gathman, N.P. Danz, D. Rokitnicki-Wojcik, and G.P. Grabas. 2014. Correlation of physical factors to coastal wetland vegetation community distribution in the Laurentian Great Lakes. Society of Wetland Scientists/Joint Aquatic Sciences Meeting, Portland, OR.

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

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

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

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

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

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

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

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

Mudrzynski, B.M., D.A. Wilcox, and A. Heminway. 2012. Habitats invaded by European frogbit (Hydrocharis morsus-ranae) in Lake Ontario coastal wetlands. INTECOL/Society of Wetland Scientists, Orlando, FL.

Mudrzynski, B.M., D.A. Wilcox, and A.W. Heminway. 2013. European frogbit (Hydrocharis morsus-ranae): current distribution and predicted expansion in the Great Lakes using niche-modeling. Society of Wetland Scientists, Duluth, MN.

Mudrzynski, B.M. and D.A. Wilcox. 2014. Effect of coefficient of conservatism list choice and hydrogeographic type on floristic quality assessment of Lake Ontario wetlands. Society of Wetland Scientists/Joint Aquatic Sciences Meeting, Portland, OR.

Mudrzynski, B.M., K. Des Jardin, and D.A. Wilcox. 2015. Predicting seed bank emergence within flooded zones of Lake Ontario wetlands under novel hydrologic conditions. Society of Wetlands Scientists. Providence, RI.

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

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

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

O'Reilly, K.E., A. McReynolds, and G.A. Lamberti. Quantifying Lake Michigan coastal wetland-nearshore linkages for sustaining sport fishes using stable isotope mixing models. Annual Meeting of the Ecological Society of America. Baltimore, MD. August 9-14, 2015.

O'Reilly, K.E., A. McReynolds, C. Stricker, and G.A. Lamberti. Quantifying Lake Michigan coastal wetland-nearshore linkages for sustaining sport fishes. State of Lake Michigan Conference. Traverse City, MI. October 28-30, 2015.

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

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

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

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

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

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

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

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

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

Schmidt, N. C., Schock, N., and D. G. Uzarski. 2013. Modeling macroinvertebrate functional feeding group assemblages in vegetation zones of Great Lakes coastal wetlands. International Association for Great Lakes Research Conference, West Lafayette, IN. June.

Schmidt, N.C., N.T. Schock, and D.G. Uzarski. 2014. Influences of metabolism on macroinvertebrate community structure across Great Lakes coastal wetland vegetation zones. Great Lakes Science in Action Symposium, Central Michigan University, Mt. Pleasant, MI. April.

Schock, N.T. and D.G. Uzarski. Stream/Drainage Ditch Impacts on Great Lakes Coastal Wetland Macroinvertebrate Community Composition. 55th International Conference on Great Lakes Research, Cornwall, Ontario.

Schock N.T., Uzarski D.G., 2013. Habitat conditions and macroinvertebrate communities of Great Lakes coastal habitats dominated by wet meadow, Typha spp. and Phragmites australis: implications of macrophyte structure changes. International Association for Great Lakes Research Conference, West Lafayette, IN. June.

Schock, N.T., B.A. Murry, D.G. Uzarski 2014. Impacts of agricultural drainage outlets on Great Lakes coastal wetlands. Great Lakes Science in Action Symposium, Central Michigan University, Mt. Pleasant, MI. April.

Schock, N.T., Schuberg, D.H., and Uzarski, D.G. 2015. Chemical and physical habitat gradients within Great Lakes coastal wetlands. 58th International Association for Great Lakes Research Conference, Burlington, VT. May.

Schoen, L.S., J.J. Student, and D.G. Uzarski. 2014. Reconstruction of fish movements between Great Lakes coastal wetlands. American Fisheries Society, Holland, MI. February.

Sherman, J.S., T.A. Clement, N.T. Schock, and D.G. Uzarski. 2012. A comparison of abiotic and biotic parameters of diked and adjacent open wetland complexes of the Erie Marsh Preserve. 55th International Conference on Great Lakes Research, Cornwall, Ontario.

Sherman, J.J., and D.G. Uzarski. 2013. A Comparison of Abiotic and Biotic Parameters of Diked and Adjacent Open Wetland Complexes of the Erie Marsh Preserve. 56th International Conference on Great Lakes Research, West Lafayette, IN. June.

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

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

Smith, D.L., M.J. Cooper, J.M. Kosiara, and G.A. Lamberti. 2013. Heavy metal contamination in Lake Michigan wetland turtles. International Association for Great Lakes Research, 56th annual meeting. June 2-6, 2013. West Lafayette, IN. Poster presentation.

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

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

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

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

Trebitz, A., J. Hoffman, G. Peterson, G. Shepard, A. Frankiewicz, B. Gilbertson, V. Brady, R. Hell, H. Wellard Kelly, and K. Schmude. 2015. The faucet snail (*Bithynia tentaculata*) invades the St. Louis River Estuary. St. Louis River Estuary Summit, Superior, Wisconsin. Mar. 30 – Apr. 1.

Tuttle, E., T.N. Brown, D.A. Albert, and *T.J. Lemein. 2013. Comparison of two plant indices: Floristic Quality Index (FQI) and an index based on non-native and invasive species. Annual Society of Wetland Scientists Conference, Duluth, MN. June 4, 2013.

Unitis, M.J., B.A. Murry and D.G. Uzarski. 2012. Use of coastal wetland types by juvenile fishes. Ecology and Evolutionary Ecology of Fishes, Windsor, Ontario. June 17-21.

Uzarski, D.G. 2011. Great Lakes Coastal Wetland Monitoring for Restoration and Protection: A Basin-Wide Effort. State Of the Lakes Ecosystem Conference (SOLEC). Erie, Pennsylvania. October 26.

Uzarski, D.G. 2011. Coastal Wetland Monitoring: Background and Design. Great Lakes Coastal Wetland Monitoring Meeting. MDEQ; ASWM. Acme, Michigan. August 29.

Uzarski, D.G., N.T. Schock, T.A. Clement, J.J. Sherman, M.J. Cooper, and B.A. Murry. 2012. Changes in Lake Huron Coastal Wetland Health Measured Over a Ten Year Period During Exotic Species Invasion. 55th International Conference on Great Lakes Research, Cornwall, Ontario.

Uzarski, D.G., M.J. Cooper, V.J. Brady, J. Sherman, and D.A. Wilcox. 2013. Use of a basin-wide Great Lakes coastal wetland monitoring program to inform and evaluate protection and restoration efforts. International Association for Great Lakes Research, West Lafayette, IN. (INVITED)

Uzarski, D.G. 2013. A Basin Wide Great Lakes Coastal Wetland Monitoring Plan. Region 5 State and Tribal Wetlands Meeting: Focusing on Wetland Monitoring and Assessment around the Great Lakes. October 31. Kellogg Biological Station, Hickory Corners, MI.

Uzarski, D.G. 2013. Great Lakes Coastal Wetland Assessments. Lake Superior Cooperative Science and Monitoring Workshop. September 24-25. EPA Mid-Continent Ecology Division Lab, Duluth, MN.

Uzarski, D.G. 2013. A Basin-Wide Great Lakes Coastal Wetland Monitoring Program. 5th National Conference on Ecosystem Restoration. July 29-August 2. Schaumburg, IL.

Uzarski, D.G., Cooper, M.J., Brady, V., Sherman, J.J., and D.A. Wilcox. 2013. Use of a Basin Wide Great Lakes Coastal Wetland Monitoring Program to inform and Evaluate Protection and Restoration Efforts. 56th International Conference on Great Lakes Research, West Lafayette, IN.

Uzarski, D., M. Cooper and V. Brady. 2014. Implementing a Basin-wide Great Lakes Coastal Wetland Monitoring Program. Webinar for Sustain Our Great Lakes, Jan. 29, 2014. On-line webinar for Great Lakes researchers, managers, agency personnel, and environmental groups. Attendance approximately 400.

Uzarski, D.G., Schock, N.T., Schuberg, D.H., Clement, T.A., and Cooper, M.J. 2015. Interpreting multiple organism-based IBIs and disturbance gradients: Basin wide monitoring. 58th International Conference on Great Lakes Research, Burlington, VT. May.

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

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

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

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

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

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

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

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

Walton, N.G., E.E.G. Giese, R.W. Howe, G.J. Niemi, N.P. Danz, V.J. Brady, T.N. Brown, J.H. Ciborowski, J.P. Gathman, G.E. Host, L.B. Johnson, E.D. Reavie, and K.E. Kovalenko. 2013. How do different taxa respond to landscape stressors in Great Lakes coastal wetlands? 98th Annual Meeting of the Ecological Society of America. Minneapolis, MN, August 4-9.

Webster, W.C. and D.G. Uzarski. 2012. Impacts of Low Water level Induced Disturbance on Coastal Wetland Vegetation. 55th International Conference on Great Lakes Research, Cornwall, Ontario.

Wheeler, R. and D.G. Uzarski. 2012. Spatial Variation of Macroinvertebrate Communities within Two Emergent Plant Zones of Great Lakes Coastal Wetlands. 55th International Conference on Great Lakes Research, Cornwall, Ontario.

Wheeler, R.L. and D.G. Uzarski. 2013. Effects of Vegetation Zone Size on a Macroinvertebrate-based Index of Biotic Integrity for Great Lakes Coastal Wetlands. 56th International Conference on Great Lakes Research, West Lafayette, IN. June.

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

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

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

Wilcox, D.A. and B.M. Mudrzynski. 2011. Wetland vegetation sampling protocols under the Great Lakes Coastal Wetland Monitoring program: experience in Lake Ontario. State of the Lakes Ecosystem Conference, Erie, PA. (INVITED)

Wilcox, D.A. and B.M. Mudrzynski. 2012. Implementing Great Lakes coastal wetlands monitoring: southern Lake Ontario. SUNY Great Lakes Research Consortium Conference, Oswego, NY. (INVITED)

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

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

Wilcox, D.A. 2012. Wetland restoration options under the Great Lakes Restoration Initiative. SUNY Great Lakes Research Consortium Conference, Oswego, NY. (INVITED)

Wilcox, D.A., D.G. Uzarski, V.J. Brady, M.J. Cooper, and T.N. Brown. 2013. Great Lakes coastal wetland monitoring program assists restoration efforts. Fifth World Conference on Ecological Restoration, Madison, WI.

Wilcox, D.A., D.G. Uzarski, V.J. Brady, M.J. Cooper, and T.N. Brown. 2014. Wetland restoration enhanced by Great Lakes coastal wetland monitoring program. Society of Wetland Scientists, Portland, OR.

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

Wilcox, D.A. 2015. Wetland restorations in the Braddock Bay Fish and WildlifecManagement Area of Lake Ontario. NY Waterfowl and Wetland Collaborative Network, Oswego, NY. (INVITED)

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

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

Publications/Manuscripts (inception through 2020)

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

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

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

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

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

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

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

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

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

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

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

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

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Appendix

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

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2. http://www.wwmt.com/news/features/top-stories/stories/Snail-harmful-to-ducks-spreading-in-Great-Lakes-63666.shtml
3. http://fox17online.com/2014/12/16/gvsu-researchers-find-more-of-invasive-snail-species-in-lake-michigan/
4. http://www.ourmidland.com/news/cmu-scientists-identify-spread-of-invasive-species/article_e9dc5876-00f4-59ff-8bcd-412007e079e8.html
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6. http://media.cmich.edu/news/cmu-institute-for-great-lakes-research-scientists-identify-spread-of-invasive-species
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10. http://whitehallmontague.wzzm13.com/news/environment/327493-my-town-waterfowl-killer-spreads-great-lakes-basin
11. http://www.timesunion.com/news/science/article/Snail-harmful-to-ducks-spreading-in-Great-Lakes-5959538.php
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16. http://theoryoflife.com/connect/researchers-track-invasive-9251724/
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20. http://www.chron.com/news/science/article/Snail-harmful-to-ducks-spreading-in-Great-Lakes-5959538.php
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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.