Great Lakes Coastal Wetland Monitoring Program

Semiannual Progress Report
October 1, 2021 – March 31, 2022

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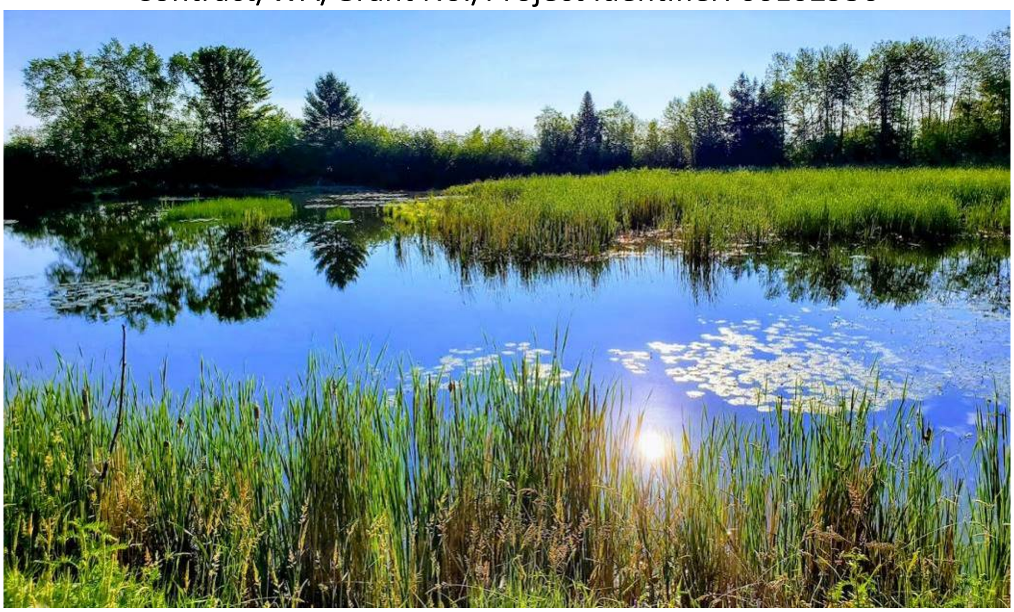

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INTRODUCTION

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 method adjustments, we updated our QAPP and have kept it updated, although relatively minor changes have had to be made since that first year. Crews sampled 176 sites that first year and roughly 200 sites per year each of the next 4 years. Data were entered into an on-line web-interface database specifically designed to hold the data.

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

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

PROGRAM ORGANIZATION

Figure 1 shows our current organization. Our project management team has not changed, but Anne Garwood of Michigan Department of Environment, Great Lakes, and Energy has moved to a new position within her agency. Our new collaborator at EGLE is Kathleen Fairchild, who will help us connect with wetland managers and restoration specialists.

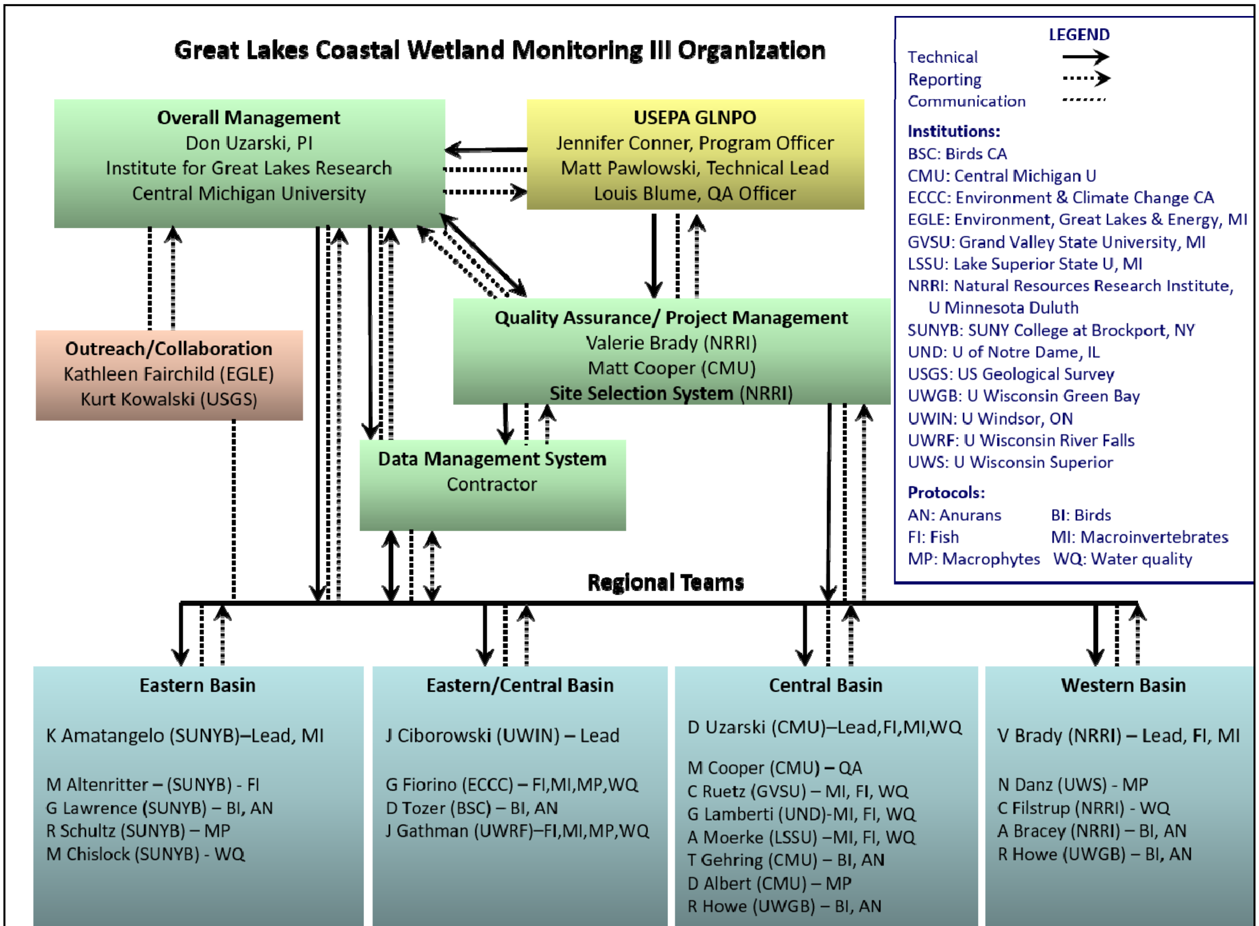

Figure 1. Current organizational chart for the program showing lines of technical direction, reporting, and communication separately.

PROGRAM TIMELINE

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

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

	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 (Oct. 1, 2021 – March 31, 2022)		Project Status* (Feb. 2021 – Jan. 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 twelve site selection was completed in March 2022. We have completed our 5-year sampling scheme twice (round 1: 2011-2015; round 2: 2016-2020) and are starting the second year of 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 are able to sample for which biota. The list of wetlands to be sampled this year (2022) was previously sampled in 2012 and 2017, 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 MANAGEMENT SYSTEM (formerly called the Site Selection Tool), completed in 2011, minor updates in 2012, 2013, 2016, 2020, 2021. Patched back together for 2022.

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

Strata

Geomorphic classes

Geomorphic classes (riverine, barrier-protected, and lacustrine) were identified for each site in the original coastal wetland GIS coverage. Many wetlands inevitably combine aspects of multiple classes, with an exposed coastal region transitioning into protected backwaters bisected by riverine elements. Wetlands were classified according to their predominant geomorphology. 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 that stratified the Great Lakes' shoreline in a manner that captured a useful cross section of the physiographic gradients in the basin. To achieve the intended stratification of physiographic conditions, a simple regionalization dividing each lake into northern and southern components, with Lake Huron being split into three parts and Lake Superior being treated as a single region, was adopted (Figure 2). The north-south splitting of Lake Michigan is common to all major ecoregions systems (Omernik / Bailey / CEC).

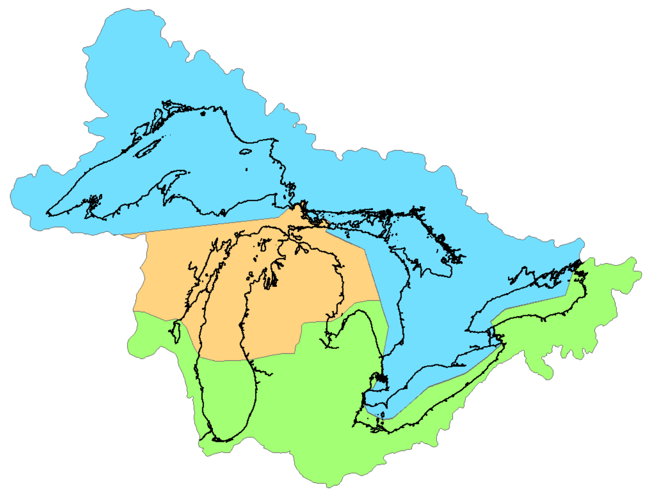

Figure 2. Divisions of lakes into regions. Note that stratification is by region *and* lake, so northern Lake Erie is not in the same region as Lake Superior, etc.

Panelization

Randomization

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 *b* of panel *E* comprised the re-sample sites. This summer (2022), we will sample panel B for the third time and the re-sample sites are from subpanel c of Panel A (so they were sampled in 2021). 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 workflow 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. Teams use the interactive site list to exchange sites with each other to ensure that as many sites as possible are sampled even if, for example, teams cannot cross the US/CA border as they normally would to sample sites that are physically nearer to them than the nearest team on the other side of the border.

Field maps

Multi-page PDF maps are generated for each site for field crews each year. The first page depicts the site using aerial imagery and a road overlay with the wetland site polygon boundary. The image also shows the location of the waypoint provided for navigation to the site via GPS. The second page indicates the site location on a road map at local and regional scales. The remaining pages list information from the database for the site, including site informational tags, team assignments, and the history of comments made about the site, including information from previous field crew visits intended to help future crews find boat launches and learn about any hazards a site poses.

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

Name	Description	Data_level
too many	Too far down randomly-ordered list, beyond sampling capacity for crews.	-1
not sampling BM	Benchmark site that will not be sampled by a particular crew.	-1
listed	Place holder status; indicates status update needed.	0
web reject	Rejected based on regional knowledge or aerial imagery in web tool.	-1
will visit	Indicates site assignment to a team with intent to sample.	0
could not access	Proved impossible to access.	-1
could not sample	Added for 2020; indicates inability of crew to sample for some reason other than safety or lack of an appropriate wetland.	-1
visit reject	Visited in field, and rejected (no lake influence, etc.).	-1
will sample	Interim status indicating field visit confirmed sampleability, but sampling has not yet occurred.	1
sampled	Sampled, field work done.	1
entered	Data entered into database system.	2
checked	Data in database system QC-checked.	3

Browse map

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

2022 SITE SELECTION

For 2022, 226 sites have been selected for sampling (Figure 3). Of these, 17 are benchmark sites. Another 15 sites are re-sample sites and 18 are pre-sample sites, which will be re-sample sites next year (2023). Benchmark, re-sample, 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 2022 site list. We are hoping that the site access issues due to high lake water levels and border closures from the global pandemic (both the US-CA border and some tribal borders) will have eased this year.

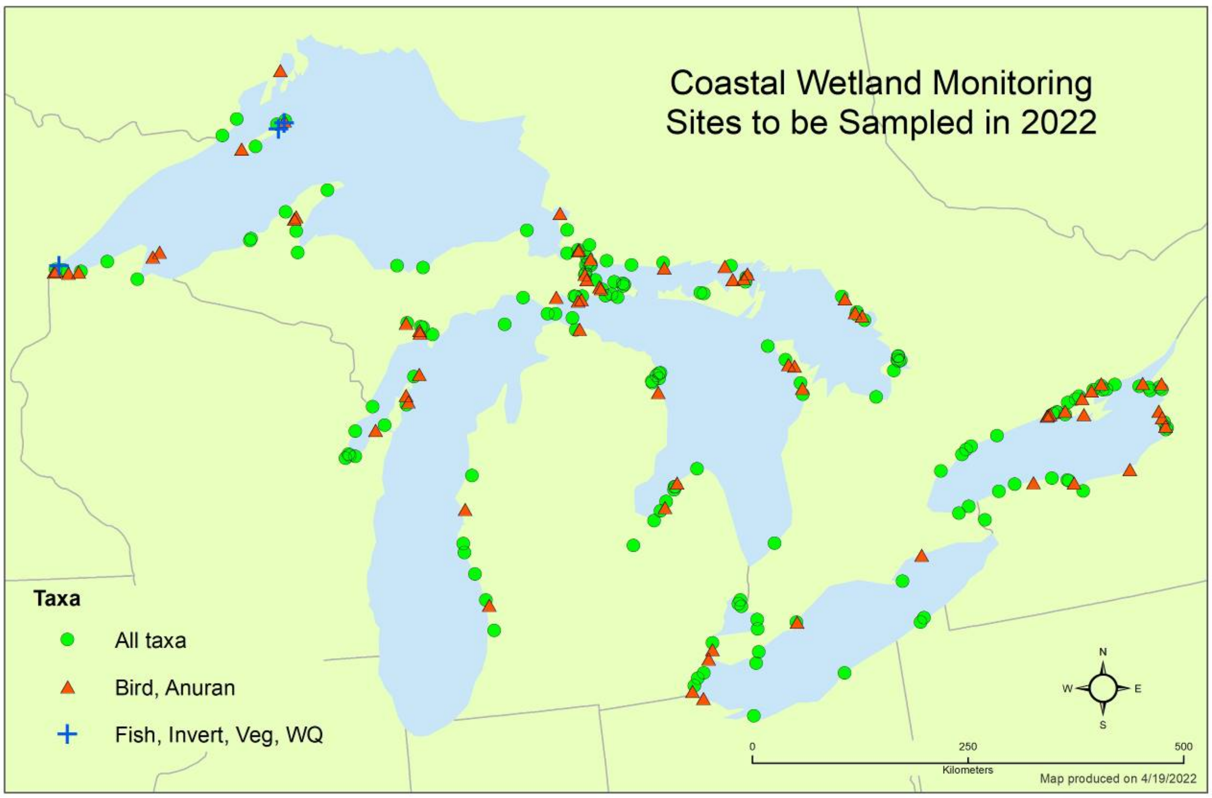

Figure 3. Locations of the 226 Great Lakes coastal wetlands to be sampled in 2022, color-coded by taxonomic groups. Sites assigned only to bird and anuran crews (due to their greater sampling capacity) are shown with a red triangle.

Benchmark sites are sites that 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.

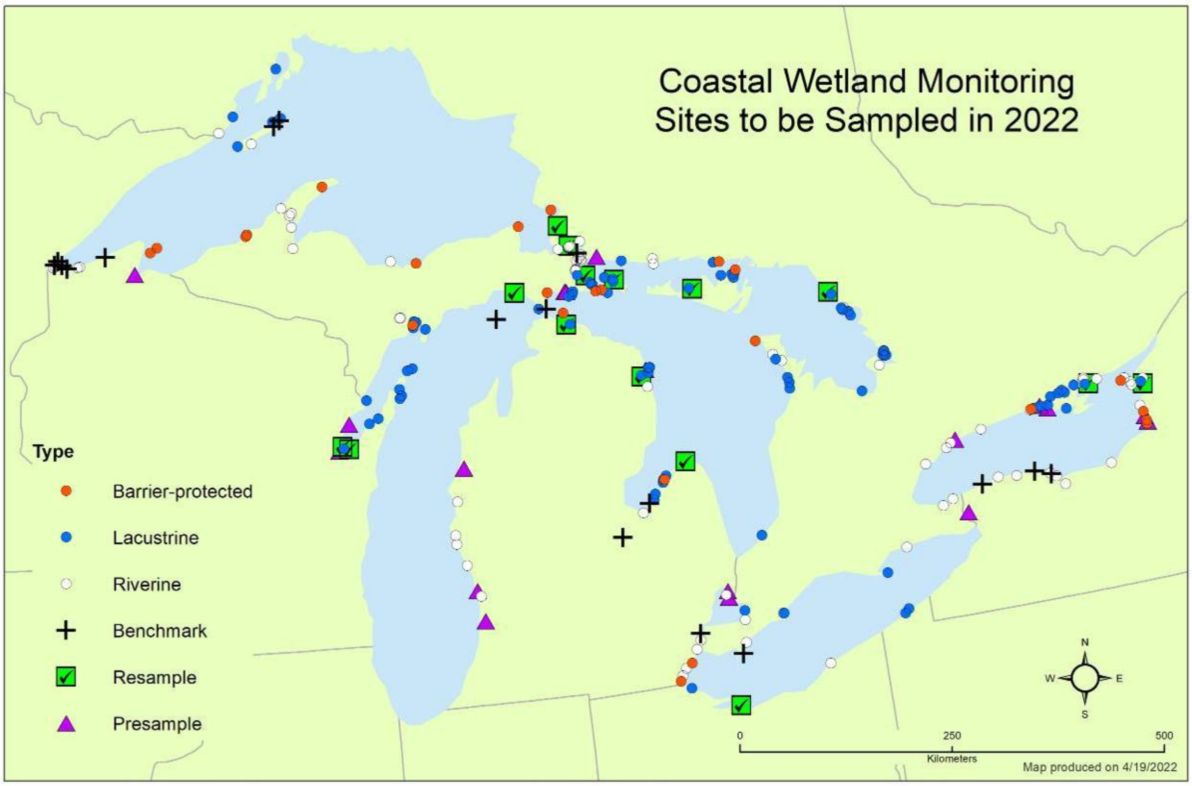

Figure 4. Locations of the 226 Great Lakes coastal wetlands to be sampled in 2022, color-coded by site type. See text for description of site types.

We now have approximately 85 sites for which at least some of their sampling is designated as "benchmark." Of these sites, 37 are to evaluate restoration efforts and 11 serve as reference sites for their area or for nearby restoration sites. The rest are more intensive monitoring sites at which the extra data will help provide long-term context and better ecological understanding of coastal wetlands. Almost all benchmark sites are in the US.

Wetlands have a "clustered" distribution around the Great Lakes due to geological and topographic differences along the Great Lakes coastline. Thus, each year several teams end up with fewer sites than they have the capacity to sample, while other teams' assigned sites exceed their sampling capacity. Within reason, teams with excess sampling capacity will expand their sampling boundaries to assist neighboring over-capacity teams in order to maximize the number of wetlands sampled. The Site Management System is used to make these changes.

Site Management System Problems in 2022

The Site Management System's server crashed at the end of 2021. This instantly brought down the entire system. The server crash was unexpected because it is a relatively new server, but it happened during a windstorm. The data and code were backed up, so no data were lost. In attempting to move the Site Management System to a new server and integrate it with that server's software, the old, poorly maintained (due to lack of funds) software was found to be incompatible with the newer server software, newer aerial image sources, and newer browser interfaces. This issue compounded as each fix caused some other code to breakdown as the programmers attempted to put the system back together.

Due to the holidays, the fact that we can only afford 10% of a programmer's time, and the severity of the software issues, it took over two months to get the Site Management System back up and running. However, we were able to get the system back on-line in time to provide crews with the site list for the 2022 sampling season. For the future integrity of this sampling program, we are pursuing additional funding to completely re-construct the Site Management System. This crash emphasized the critical importance of this system to the running of our program.

TRAINING

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

The following is a synopsis of the training to be conducted by PIs each spring. See individual team reports for how each team plans to train safely yet effectively now that we are transitioning to dealing with Covid-19 as being endemic rather than a pandemic. In general, each PI or field crew chief trains all field personnel on meeting the data quality objectives for each element of the project; this includes reviewing the most current version of the QAPP, covering site verification procedures, providing hands-on training for each sampling protocol, and reviewing record-keeping and archiving requirements, data auditing procedures, and certification exams for each sampling protocol. All field crew members are required to pass all training certifications before they are allowed to work unsupervised. Those who do not pass all training aspects are only allowed to work under the supervision of a crew leader who has passed all training certifications.

Training for bird and anuran field crews includes tests on anuran calls, bird vocalizations, and bird visual identification. These tests are based on an online system established at the University of Wisconsin, Green Bay – see http://www.birdercertification.org/GreatLakesCoastal. In addition, individuals are evaluated for proficiency in completing field sheets, identifying birds by sight and sound in the field, and identifying anurans by sound in the field (visual ID is not necessary). Field evaluation of observers' abilities to detect distant or soft bird and anuran calls ensures observers' hearing falls within acceptable ranges, though they may also get their hearing checked with audio testing. Field training is also completed to ensure guidelines in the QAPP are followed: rules for site verification, safety issues including caution regarding insects (e.g., tick-borne diseases), GPS and compass use, and record keeping.

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

Training for fish and invertebrate crews will now include specific instructions for sampling in deep water. These techniques were trialed in 2019 and found to work to allow sampling in at least somewhat deeper water than we have been sampling. Specifically, to sample invertebrates in depths greater than 1 m, D-frame dip net handles were extended so that sampling can be done from a boat by moving around the boat and allowing the boat to swing on its anchor. 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 and data are coded accordingly.

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

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

CERTIFICATION

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

DOCUMENTATION AND RECORD

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

Regional team leaders archive copies of the testing and certification records of all field crew members. Summaries of these records are also archived with the lead PI (Uzarski), and the 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 hold 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 macrophytic vegetation, fish, macroinvertebrates, anurans and birds. Separate data entry/editing forms are created for data entry based on database table schema information that is stored in a separate PostgreSQL schema. Data entry/editing forms are password-protected and can be accessed only by users that have “Project Researcher” or “Admin” credentials associated with their CWMP user account and permissions for specific taxa group(s).

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

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

- Domain-specific "helper" utilities, such as generation of fish length records based on fish count records;
- Dual-entry inconsistency highlighting for anuran and bird groups using dual-entry for quality assurance;
- Tools for adding new taxa records or editing existing taxa records for the various taxonomic groups; and
- GPS waypoint file (*.gpx) uploading utilities and waypoint processing to support matching of geographic (latitude/longitude) coordinates to sampling points.

The CWMP data management system also provides separate webpages that allow researchers to download "raw" data for the various taxonomic groups as well as execute and download custom queries that are useful for supporting dataset review and QA/QC evaluations as data entry proceeds during, and following each field season. Users from state management agencies are able to access the separate download pages for raw data and custom queries. Such organizations include GLNPO and its subcontractors and 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 2021 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, planned to occur in fall and spring of each program year.

In addition to providing CWMP researchers with data entry and download access, the CWMP data management team is providing ongoing technical support and guidance to GLNPO to support its internal management and application of the QA/QC'd monitoring datasets. GLNPO, with support from contractors, 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 (2011-2021, 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; Tables 6 and 7). In 2020 we completed sampling these wetlands a second time for the second complete round of coastal wetland assessment (2016-2020). Note that this total number of wetlands sampled 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; Tables 6 and 7).

Round 3 (2021-2015) began summer 2021 with teams sampling 175 wetlands (again, fewer than in Round 2 due to the pandemic; Tables 6 and 7).

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, Tables 6 and 7). When compared to the total number of wetlands targeted to be sampled by this project (Table 3), we are achieving our goals of sampling 20% of US wetlands per year, both by count and by area. However, each year 60-65% of total sites sampled are US coastal wetlands, with 75-80% of the wetland area sampled on the US side. Overall, we have sampled most of the large, surface-connected Great Lakes coastal emergent wetlands by count and by area. A few wetlands currently cannot be sampled due to a lack of safe access or a lack of permission to cross private lands.

Ability to sample sites depends not only on access but also on water levels. Teams were able to sample more sites in 2014 compared to earlier years due to higher lake levels on Lakes Michigan and Huron, which allowed crews to access sites and areas that have been dry or inaccessible. 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.

Table 6. Counts, areas, and proportions of US 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.

US	Site count	Site %	Site area	Area %
Round 1 (2011 – 2015)				
2011	126	72%	22,008	87%
2012	124	60%	21,845	73%
2013	130	65%	18,939	73%
2014	144	67%	26,836	80%
2015	134	64%	26,681	73%
US total Round 1	**658**	**65%**	**116,309**	**77%**
Round 2: 2016 – 2020				
2016	129	67%	24,446	85%
2017	139	67%	30,703	80%

2018	125	65%	17,715	82%
2019	135	64%	30,281	80%
2020	119	69%	29,325	77%
US total Round 2	**647**	**66%**	**132,470**	**82%**
Round 3: 2021 – 2025				
2021	122	70%	24,734	85%
US total Round 3	**122**	**70%**	**24,734**	**85%**

Because of the Covid-19 global pandemic and because of continued high water, about 25 fewer sites than usual could be sampled during summer 2020. The pandemic created the unusual situation of some field crews not being allowed to cross state borders or travel to areas deemed to be a high risk for Covid-19 spread. Moreover, no field crews were allowed to cross the US-Canada border in summer 2020. In a more typical year, 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 in 2020 or 2021 because no team could get there due to logistics or safety. We are hopeful that field crews will have fewer access issues related to Covid-19 during the 2022 field season.

Table 7. Counts, areas, and proportions of CA 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.

Canada	Site count	Site %	Site area	Area %
Round 1: 2011 - 2015				
2011	50	28%	3,303	13%
2012	82	40%	7,917	27%
2013	71	35%	7,125	27%
2014	72	33%	6,781	20%
2015	77	36%	10,011	27%
CA total Round 1	**352**	**35%**	**35,137**	**23%**
Round 2: 2016 - 2020				
2016	63	33%	4,336	15%
2017	70	33%	7,801	20%
2018	67	35%	3,356	18%
2019	76	36%	7,746	20%
2020	55	32%	8,603	23%
CA total Round 2	**331**	**34%**	**31,843**	**18%**

Round 3: 2021 - 2025				
2021	53	30%	4,264	15%
CA total Round 3	**53**	**30%**	**4,264**	**15%**
Overall Totals Round 1	**1010**		**151,446**	
Overall Totals Round 2	**978**		**164,312**	
Overall Totals Round 3	**175**		**28,999**	

BIOTIC COMMUNITIES AND CONDITIONS (BASED ON 2011-2021 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.

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

Table 8. Bird and anuran species in wetlands; summary statistics by country. Data from 2011 through 2021.

Country	Site count	Mean	Max	Min	St. Dev.
Birds					
Can.	616	28.6	64	5	10.2
U.S.	1189	23.8	60	2	10.5
Anurans					
Can.	546	4.6	8	0	1.7
U.S.	1071	4.1	8	0	1.3

Bird and anuran data in Great Lakes coastal wetlands by lake (Table 9) 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 9). Similarly, there was little variability by lake in maximum or minimum numbers of species. At some benchmark sites, and occasionally during unusually cold spring weather, no calling anurans were heard.

Table 9. Bird and anuran species found in Great Lakes coastal wetlands by lake. Mean, maximum, and minimum number of species per wetland for wetlands sampled from 2011 through 2021.

	Birds				Anurans			
Lake	**Sites**	**Mean**	**Max**	**Min**	**Sites**	**Mean**	**Max**	**Min**
Erie	218	28.0	54	5	221	3.8	7	0
Huron	543	25.3	64	2	459	4.4	8	0
Michigan	327	25.7	60	2	295	4.0	7	0
Ontario	476	24.0	54	7	445	4.8	8	1
Superior	241	25.7	52	9	197	3.9	8	0

An average of 10 to 13 fish species were collected in Canadian and US Great Lakes coastal wetlands, respectively (Table 10). 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 24 (CA) or 28 (US) fish species. The average number of non-native fish species per wetland was approximately one, though some wetlands had as many as 6 (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 10. Total fish species in wetlands, and non-native species; summary statistics by country for sites sampled from 2011 through 2021.

Country	Sites	Mean	Max	Min	St. Dev.
Overall					
Can.	353	9.8	24	2	3.7
U.S.	744	12.6	28	2	4.9
Non-natives					
Can.	353	0.8	5	0	0.9
U.S.	744	0.9	6	0	1.0

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.

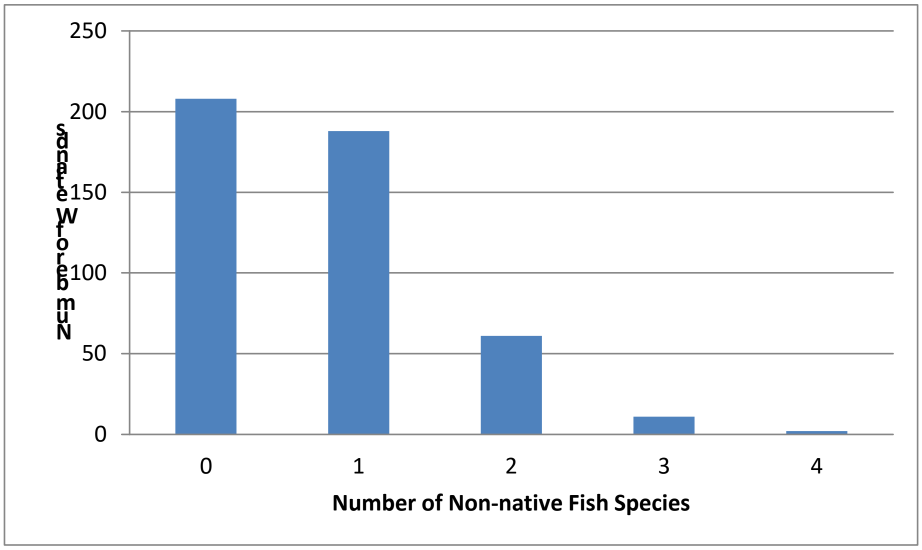

Figure 5. Number of Great Lakes coastal wetlands containing non-native fish species. Data from 2016 through 2020.

Total fish species did not differ greatly by lake, averaging 11-13 species per wetland (Table 11). All lakes but Ontario had wetlands with 27-28 species of fish. Because sites in need of restoration are included, some of these sites had very few fish species, as low as two. Wetlands averaged 1 non-native fish species captured. 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 11. Fish total species and non-native species found in Great Lakes coastal wetlands by lake Mean, maximum, and minimum number of species per wetland. Data from 2011 through 2021.

		Fish (Total)			Non-native		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	146	11.5	28	2	1.5	5	0
Huron	381	11.5	27	2	0.6	3	0
Michigan	172	12.4	28	4	0.9	5	0
Ontario	265	10.9	23	2	0.9	4	0
Superior	133	13.1	28	3	0.9	6	0

The average number of macroinvertebrate taxa (taxa richness) per site was about 38 (Table 12), 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 12). 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 12. Total macroinvertebrate taxa in Great Lakes coastal wetlands, and non-native species; summary statistics by country. Data from 2011 through 2021.

Country	Sites	Mean	Max	Min	St. Dev.
Overall					
Can.	407	38.2	76	13	11.2
U.S.	843	37.7	86	12	13.4
Non-natives					
Can.	407	0.6	4	0	0.9
U.S.	843	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 33-42 taxa with lakes Ontario and Erie having lower averages than the upper lakes (Table 13). 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 60-80 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 13. 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 2011 through 2021.

		Macroinvertebrates (Total)			Non-native		
Lake	Sites	Mean	Max	Min	Mean	Max	Min
Erie	161	34.1	69	17	1.0	4	0
Huron	430	40.4	80	12	0.7	5	0
Michigan	206	39.0	86	14	0.8	4	0
Ontario	294	33.1	62	16	0.7	4	0
Superior	159	42.0	69	19	0.2	2	0

There is little variability among lakes in non-native taxa occurrence, although Lake Superior wetlands had fewer non-native invertebrates (Table 13). In each lake there were some wetlands in which we found no non-native macroinvertebrates. As noted above, however, this does not necessarily mean that these sites do not contain non-native macroinvertebrates.

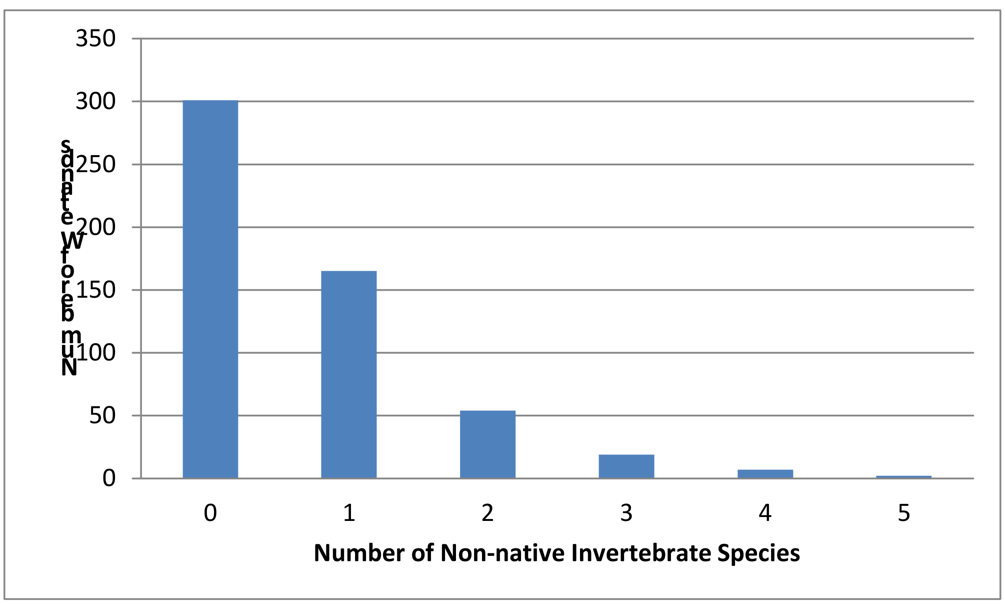

Figure 6. Number of Great Lakes coastal wetlands containing non-native invertebrate species. Data from 2016-2020 .

We found zero non-native aquatic macroinvertebrates in 55% of Great Lakes coastal wetlands sampled from 2016-2020 (Figure 6), but in a handful of wetlands we found as many as 4-5 non-native invertebrate taxa.

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

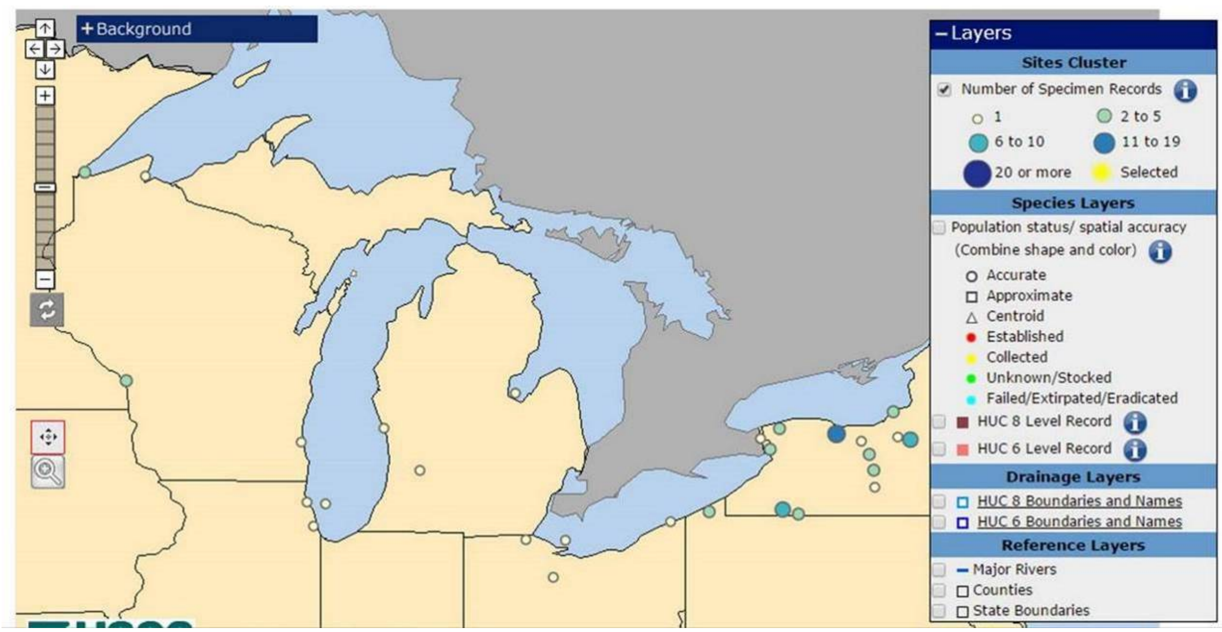

Figure 7. Locations of *Bithynia tentaculata* in USGS NAS website PRIOR to our project providing additional locations where they were collected.

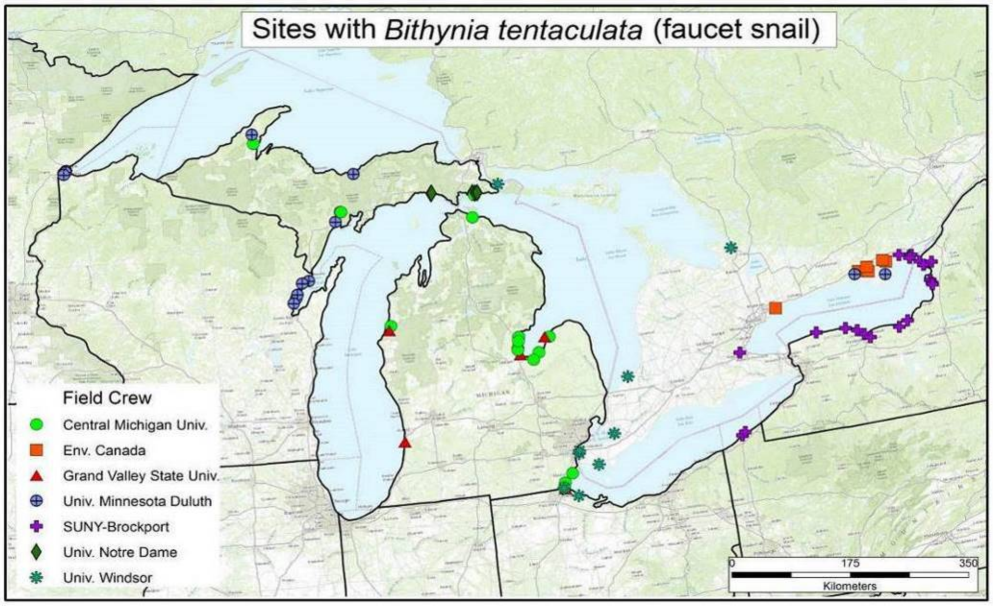

Figure 8. Locations of *Bithynia tentaculata* found by CWM crews, 2011 - 2013.

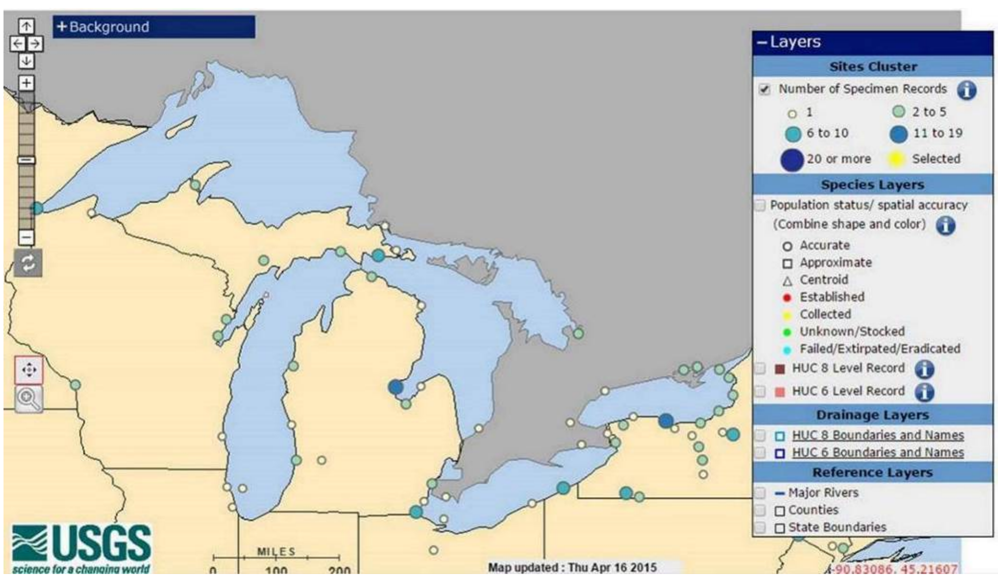

Figure 9. Locations of *Bithynia tentaculata* in USGS NAS website AFTER our project provided additional locations where they were collected; compare to Figure 6.

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

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

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

We also provided USGS with locations of other non-native macroinvertebrates and fish. The invasive macrophyte information had previously been provided to websites that track these locations, and reported to groups working on early detection and eradication. On average, there were approximately 40 macrophyte species per wetland (Table 14) with a maximum number of 100 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.

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 14). 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 14. Total macrophyte species and non-native macrophytes in Great Lakes coastal wetlands; summary statistics by country.

Country	Site count	Mean	Max	Min	St. Dev.
Overall					
Can.	427	39.4	87	5	16.3
U.S.	848	40.2	100	0	16.8
Non-native					
Can.	427	5.3	14	0	3.0
U.S.	848	4.6	21	0	3.1

Lake Erie wetlands had the lowest mean number of macrophyte species (25, Table 15), with the other lakes' wetlands having higher mean numbers of species (38-45, Table 15). 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 15). 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 all lakes where we did not detect invasive plants.

Table 15. Macrophyte total species and non-native species found in Great Lakes coastal wetlands by lake. Mean, maximum, and minimum number of species per wetland. Data from 2011 through 2021.

		Macrophytes (Total)			Non-native		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	167	25.2	69	1	5.8	18	0
Huron	431	45.5	100	3	3.9	21	0
Michigan	200	42.1	83	4	4.9	12	0
Ontario	319	39.7	87	8	7.0	16	0
Superior	158	38.1	77	0	2.0	7	0

Our macrophyte data have reinforced our understanding of the numbers of coastal wetlands that contain non-native plant species (Figure 10). Only 7% of 556 sampled wetlands lacked non-native species, leaving 93% with at least one. Sites were most commonly invaded by up to 7 non-native plant species and 13% of sites contained 8 or more non-native species. Detection of non-native species is more likely for plants than for organisms that are difficult to collect such as fish and other mobile fauna, but we may still be missing small patches of non-natives in some wetlands.

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

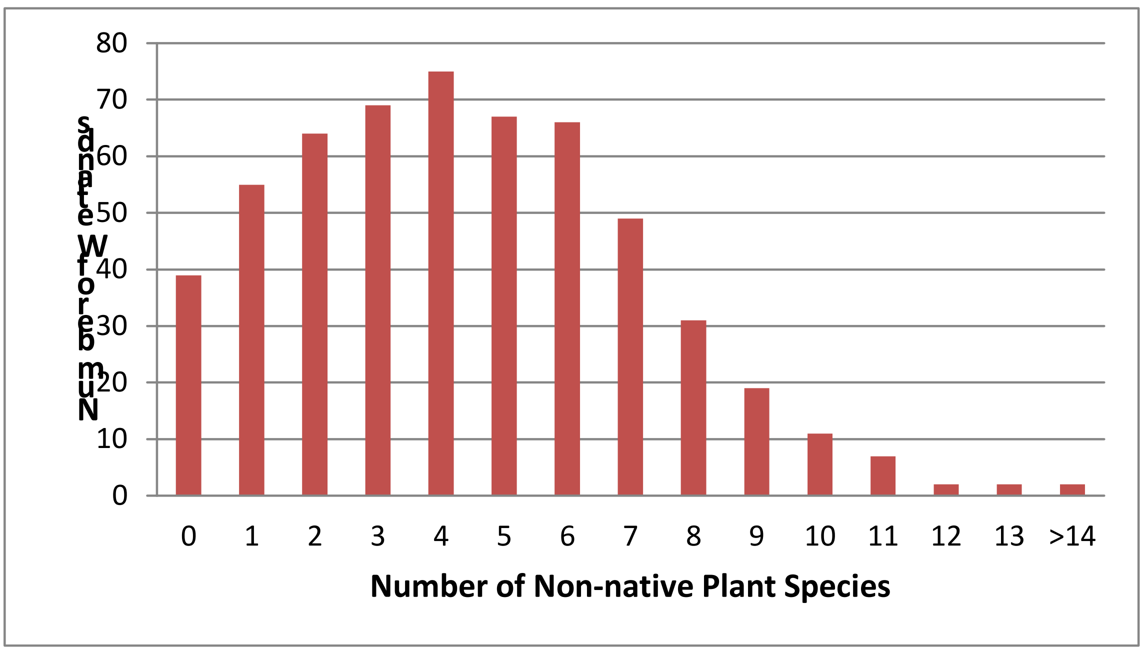

Figure 10. Number of Great Lakes coastal wetlands containing invasive plant species based on 2016 through 2020 data.

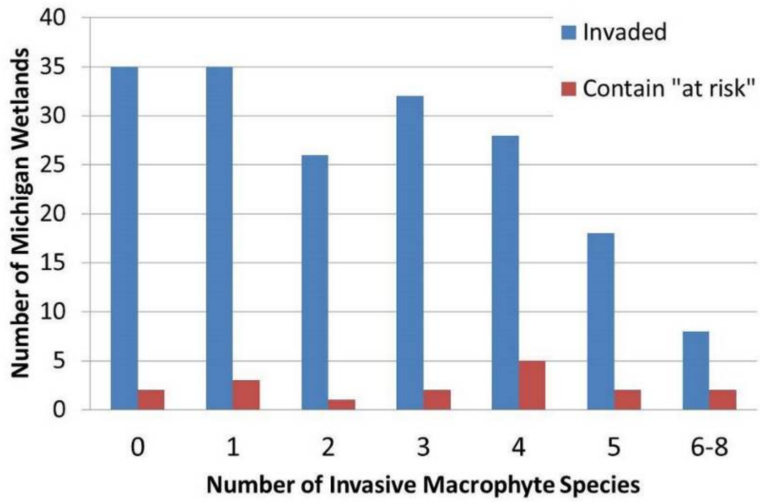

Figure 11. Number of state of Michigan Great Lakes coastal wetlands containing both invasive plant species and “at risk” plant species, based on 2011 through 2014 data.

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

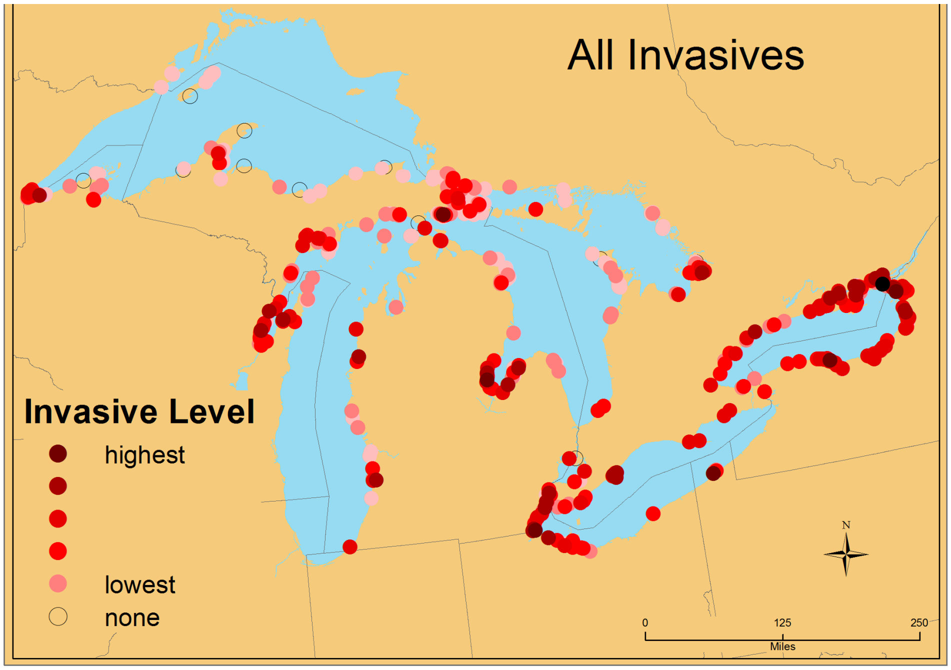

Figure 12. Level of "invadedness" of Great Lakes coastal wetlands for all non-native taxa combined across all taxonomic groups, based on data from 2011-2014.

WETLAND CONDITION (BASED ON 2011 – 2021 DATA UNLESS OTHERWISE NOTED)

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

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

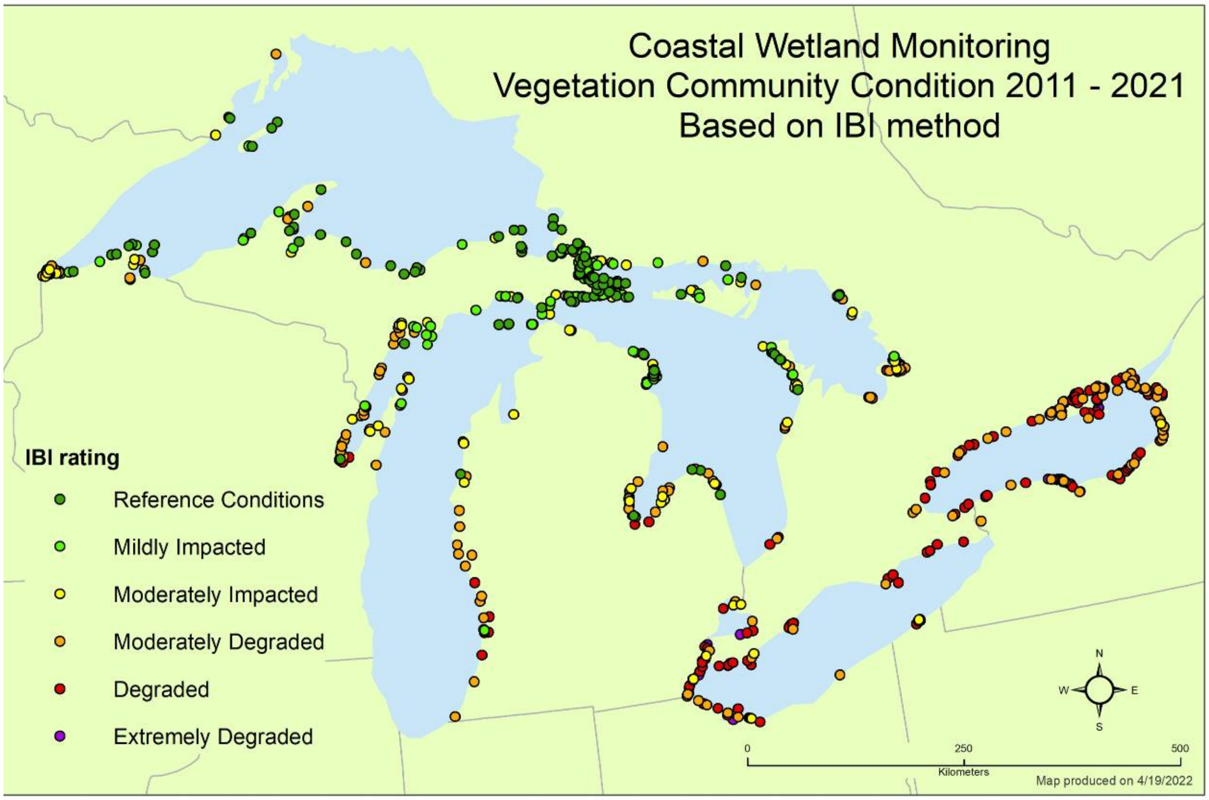

Figure 13. Condition of coastal wetland vegetation at sites across the Great Lakes. Circle color indicates vegetation community quality. The indicator is labeled "draft" while this indicator is investigated for robustness against varying water levels and latitude. Based primarily on data collected between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

The map (Figure 13) shows the distribution of Great Lakes coastal wetland vegetation index scores across the basin. Note that there are long stretches of Great Lakes coastline that do not have coastal wetlands due to topography and geology. Sites with low FQI scores are concentrated in the southern Great Lakes, where there are large amounts of both agriculture and urban development, and where water levels may be more tightly regulated (e.g., Lake Ontario), while sites with high FQI scores are concentrated in the northern Great Lakes. Even in the north, an urban area like Duluth, MN may have high quality wetlands in protected sites and lower quality degraded wetlands in the lower reaches of estuaries (drowned river mouths) where there are legacy effects from the pre-Clean Water Act era, along with nutrient enrichment or heavy siltation from industrial development and/or sewage effluent. Benchmark sites in need of restoration will also have lower condition scores.

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

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

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

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

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

Another of the IBIs that was developed by the Great Lakes Coastal Wetlands Consortium uses the aquatic macroinvertebrates found in several of the most common vegetation types in Great

Lakes coastal wetlands: sparse bulrush (*Schoenoplectus*), dense bulrush (*Schoenoplectus*), and wet meadow (multi-species) zones. We have calculated these IBIs for sites sampled from 2011 through 2018 that contain these habitat zones (Figure 14). In 2019 we had a major shift in the taxonomy of some invertebrates (primarily snails and mollusks) used in the calculation of some indicator metrics due to taxonomic updates and revisions. Thus, the invertebrate IBI map (Figure 14) in this report should not be compared to the maps shown in previous reports. However, this IBI has been calculated for all sites with appropriate zones and invertebrate data for all years.

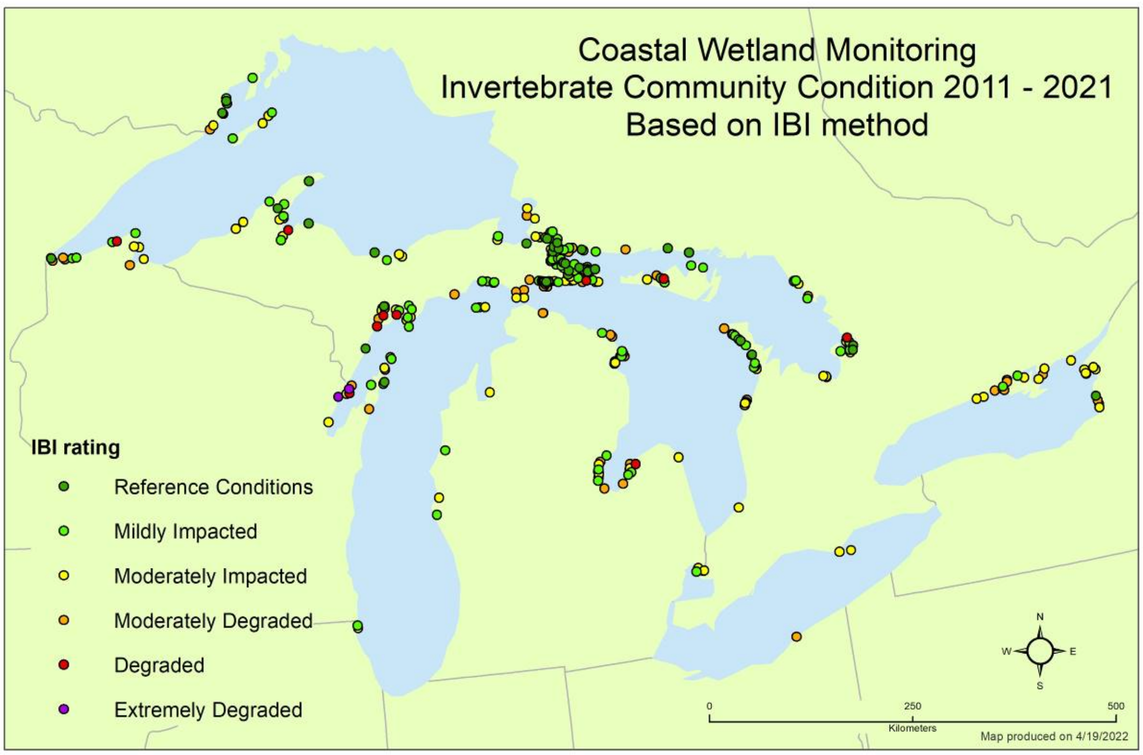

Figure 14. Condition of coastal wetland macroinvertebrate communties at sites with bulrush or wet meadow zones. Based primarily on data collected between 2016 through 2020 with data from 2011-2015 used for sites that were only sampled in those years.

The lack of sites on lakes Erie and Ontario and southern Lake Michigan is due to either a lack of wetlands (southern Lake Michigan) or because these areas do not contain any of the three specific vegetation types that GLCWC used to develop and test the invertebrate IBI. Many areas contain dense cattail stands (e.g., southern Green Bay, much of Lake Ontario) for which we do not yet have a published macroinvertebrate IBI. We are developing IBIs for additional vegetation zones, but these have not yet been validated so they are not included here.

We are now able to report updated and improved fish IBI scores for wetland sites containing bulrush, cattail, lily, or SAV zones (Figure 15). Because of the prevalence of these vegetation types in wetlands throughout the Great Lakes basin, this indicator provides more site scores than the macroinvertebrate indicator. Because these are updated and adjusted indicators, the map image in this report should not be compared to fish IBI map images in previous reports. However, all sites reporting fish data from zones applicable to the new fish IBIs are shown here, regardless of the year they were sampled.

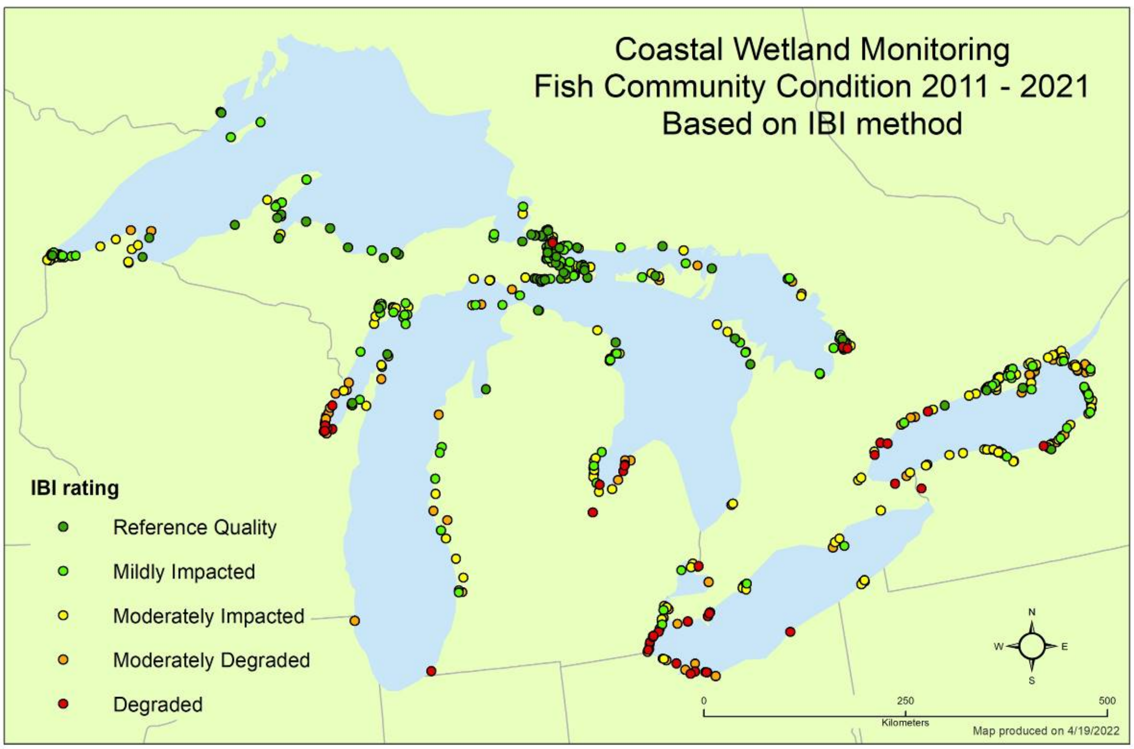

Figure 15. Condition of coastal wetland fish communties at sites with bulrush, cattail, lily, or submerged aquatic vegetation zones. Based primarily on data collected between 2016 through 2020 with 2011-2015 data used for sites that were only sampled in those years.

To develop the new fish IBI, fish community metrics were evaluated against numerous indices of anthropogenic disturbance derived from measurements of water quality and surrounding land cover. Disturbance indices included individual land cover and water quality variables, principal components combining land cover and water quality variables, a previously published landscape-based index (SumRel; Danz *et al*. 2005), and a rank-based index combining land cover and water quality variables (SumRank; Uzarski *et al*. 2005). Multiple disturbance indices were used to ensure that IBI metrics captured various dimensions of human disturbances.

We divided fish, water quality, and land cover data (2011-2015 data) into separate "development" and "testing" sets for metric identification/calibration and final IBI testing, respectively. Metric identification and IBI development generally followed previously established methods (e.g., Karr *et al*. 1981, USEPA 2002, Lyons 2012) in which 1) a large set of candidate metrics was calculated; 2) metrics were tested for response to anthropogenic disturbance or habitat quality; 3) metrics were screened for responses to anomalous catches of certain taxa, for adequate range of responses, and for highly redundant metrics; 4) scoring schemes were devised for each of the final metrics; 5) the final set of metrics was optimized to improve the fit of the IBI to anthropogenic disturbance gradients; and 6) the final IBI was validated against an independent data set.

Final IBIs were composed of 10-11 fish assemblage metrics for each of four vegetation types (bulrush [*Schoenoplectus* spp.], cattail [*Typha* spp.], water lily [*Brassenia, Nuphar, Nymphaea* spp.], and submersed aquatic vegetation [SAV, primarily *Myriophyllum* or *Ceratophyllum* spp.]). Scores of all IBIs correlated well with values of anthropogenic disturbance indices using the development and testing data sets. Correlations of IBIs to disturbance scores were also consistent among each of the five years. A manuscript describing development and testing of this IBI has been published (Cooper *et al.* 2018).

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

We refined the IEC method in two notable ways. Specifically, we used an improved reference gradient developed by Elliott *et al.* (in prep) and restricted the analysis to a suite of marsh-obligate or disturbance-associated species. Details of the analysis are provided in a manuscript that we will be submitting for publication. Jung *et al*. (2020) applied a similar approach in their recent application of the IEC in coastal wetlands of Lake Erie and Lake Michigan. New this time, we created the BR functions based on the 2011-2015 data (the low water years) to avoid the complications that the higher water in the second round of sampling is creating.

We quantified BR functions for 15 species or species groups (Table 16) that use non-woody coastal wetlands for nesting or foraging and are sensitive to the environmental reference gradient described above. Eight of these taxa consist of two or more ecologically similar species, and a ninth group combined three rare species (Northern Harrier, Black-crowned Night-Heron, and Wilson’s Snipe) that were not frequent enough to yield meaningful species-specific BR functions. One species, European Starling, is a non-native bird that uses wetlands occasionally in human-disturbed landscapes.

Table 16. Species and species groups used for calculation of Index of Ecological Condition (IEC) metrics.

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

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

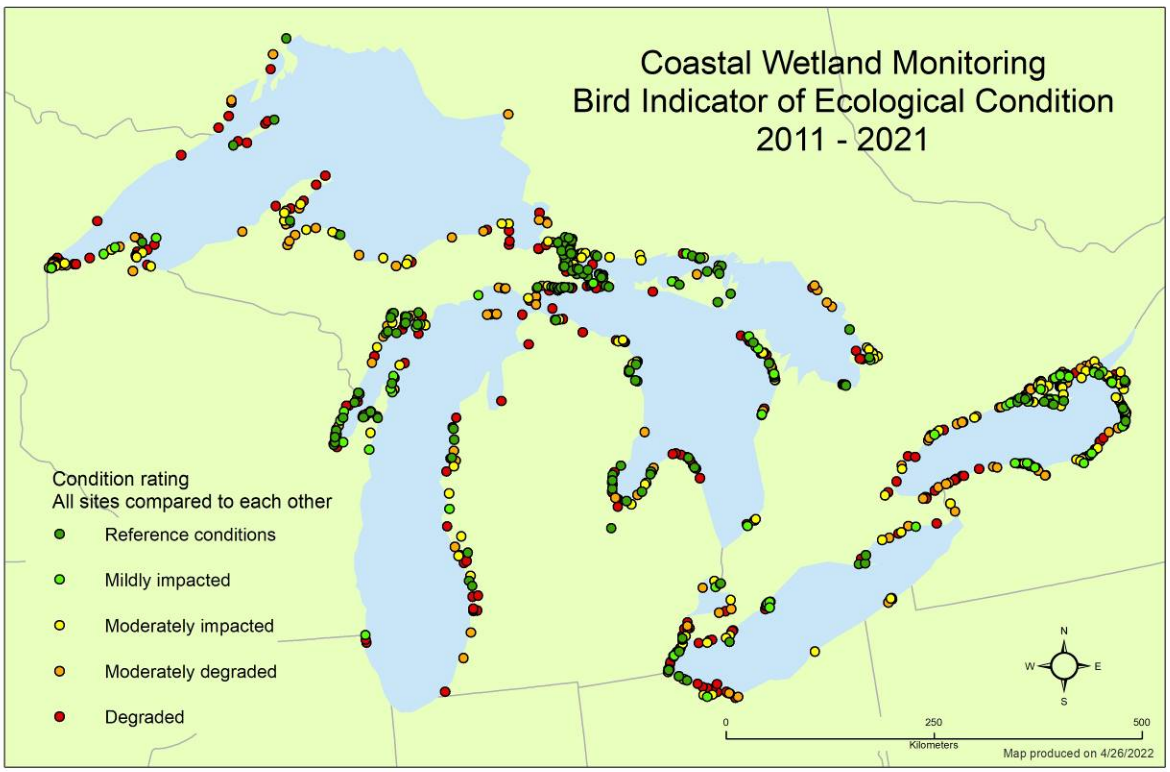

Figure 16. Condition of coastal wetland bird communties. This indicator is based on the IEC method (see text) using data collected primarily between 2016 and 2021, with data from 2011-2015 used to create the the baseline for the indicator but only used to calculate the actual wetland condition at a site if no other data were available.

Note that high IEC values occur in all regions, suggesting that quality coastal wetlands for birds are widely distributed across the Great 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-Lake Huron corridor, 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 (2011-2020). 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*).

Highest anuran IEC values (Figure 17) were obtained for wetlands in Lake Michigan during high water years, 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.

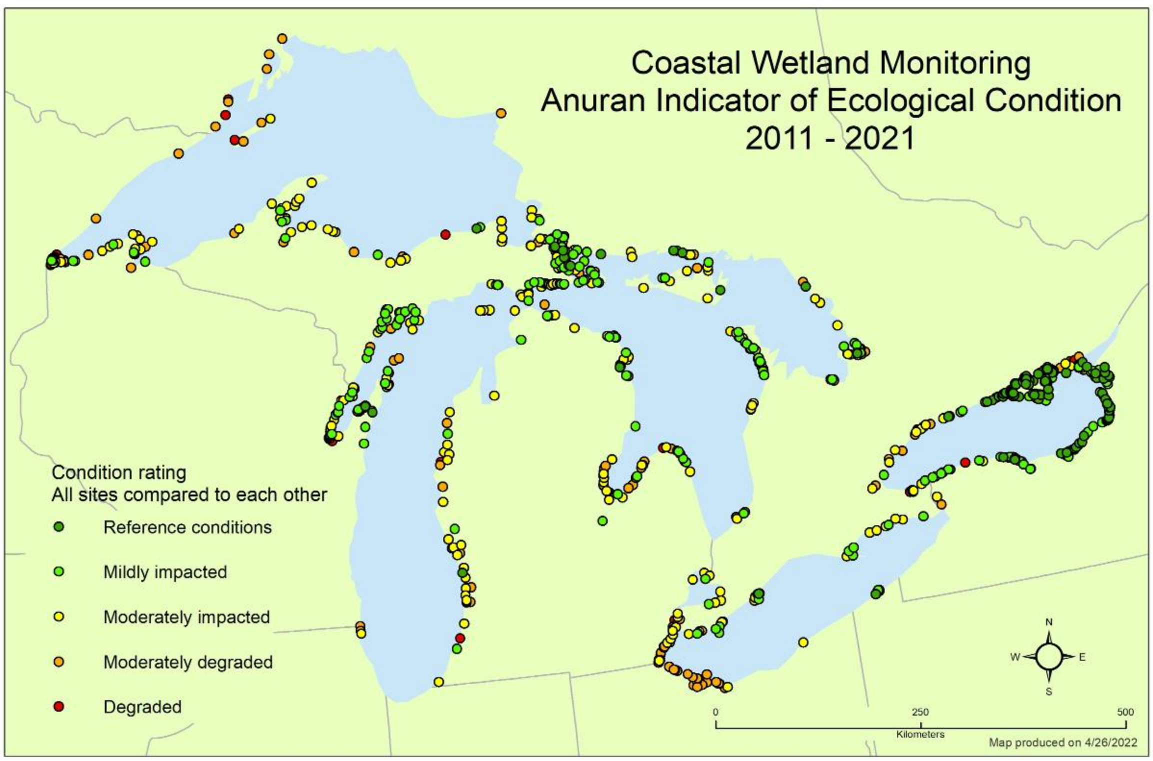

Figure 17. Condition of coastal wetland calling anuran communities. This indicator is based on the IEC method (see text) using data collected primarily between 2016 and 2021, with data from 2011-2015 used to create the the baseline for the indicator but only used to calculate the actual wetland condition at a site if no other data were available.

Finally, we have developed a water quality and 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 plant morphotype (Figure 18).

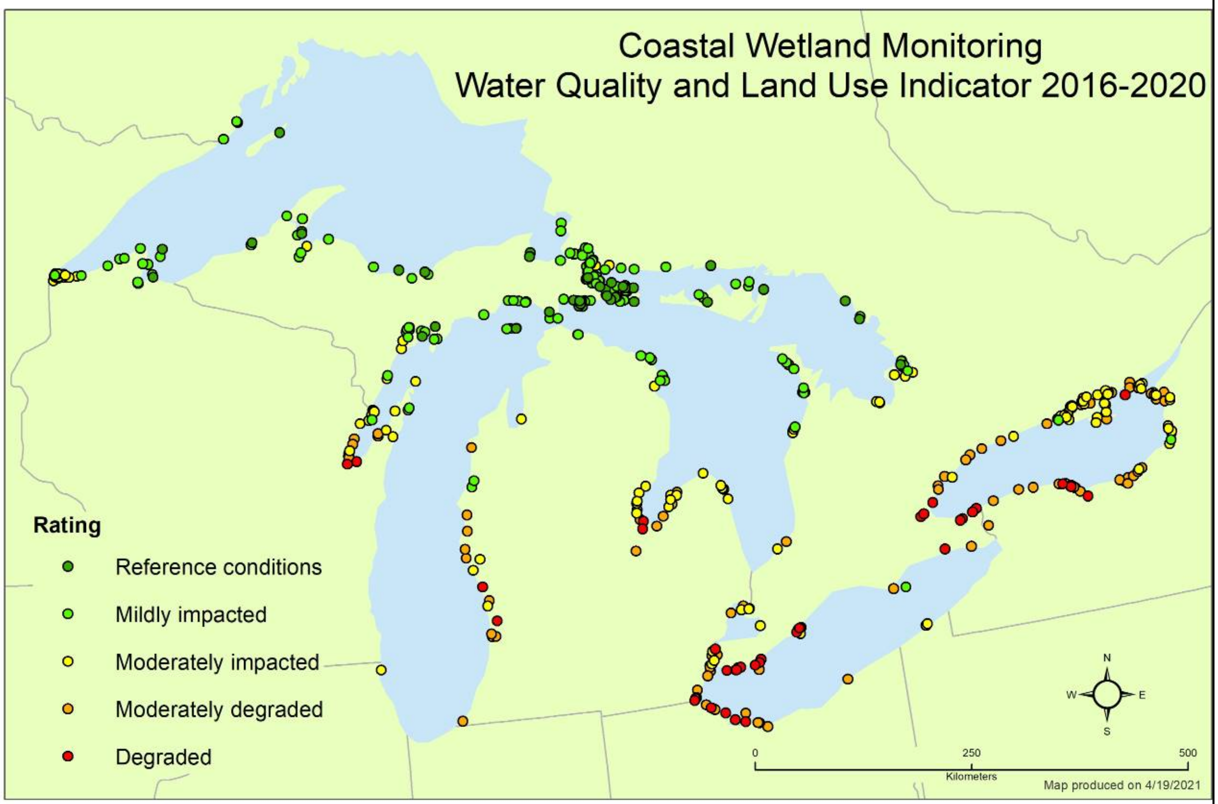

Figure 18. Disturbance gradient (SumRank) indicator. This indicator is based on landscape stressor data, site-based stressor data, and site water quality data. This is based on data collected from 2016 through 2020.

PUBLIC ACCESS WEBSITE

The Coastal Wetlands Monitoring Program (CWMP) website provides efficient access to program information and summary results for coastal managers, agency personnel, and the interested public (Figure 19). As previously noted, the CWMP website was redeveloped and upgraded by LimnoTech and transitioned from an NRRI server to a permanent web hosting environment at Central Michigan University in spring 2016. The official launch of the new CWMP website occurred on April 26, 2016, including the public components of the website and data management tools for CWMP principal investigators and collaborators. Since that time, coastal managers and agency personnel have used the 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 19. Front page of the Great Lakes Coastal Wetland Monitoring public website, www.greatlakeswetlands.org.

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

- **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 20):

- 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 21); and
- Reporting of basic site attributes (site name, geomorphic type, latitude, longitude, and sampling years) and general monitoring observations for the site (e.g., hydrology, habitat, disturbances).

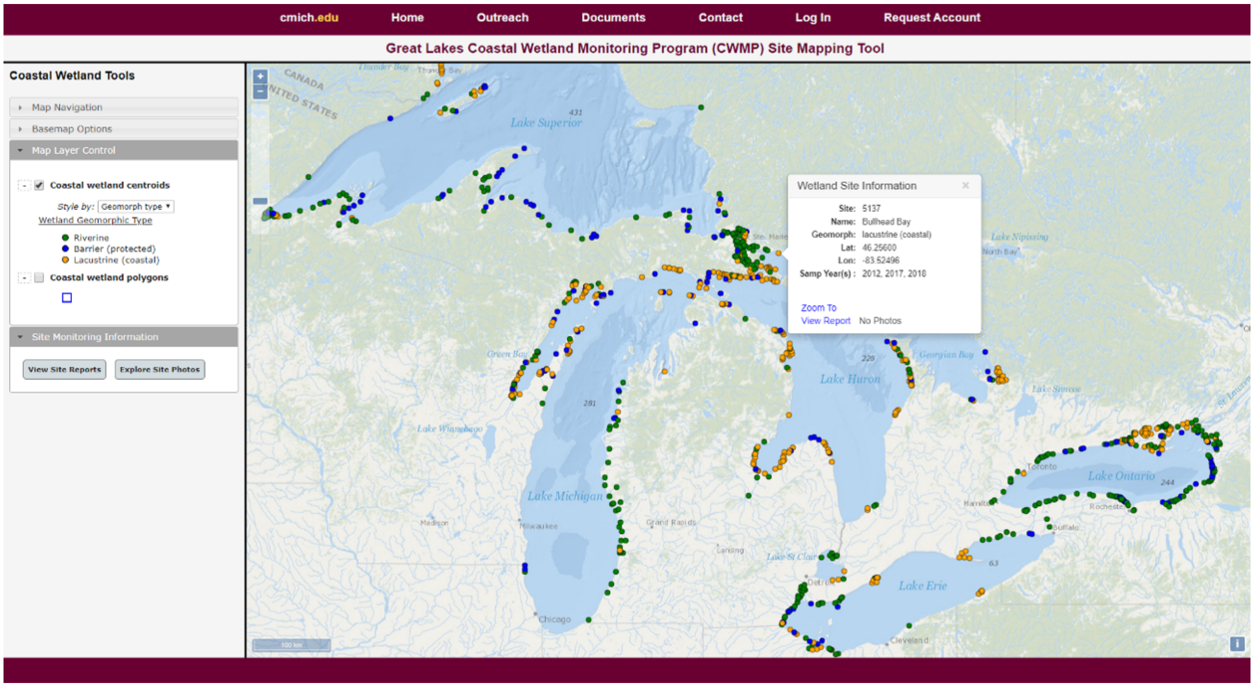

Figure 20. Coastal Wetland Mapping Tool – Public Version (geomorphic type view).

In addition to the features made available at the "Public" access level, users with "Level 1" (*Site Metrics*) access to the website can currently obtain information regarding IBI scores for vegetation, invertebrates, and fish; *Index of Ecological Condition* (IEC) scores for anurans and birds; and a *Water Quality and Land Use Index*, which functions as a Disturbance Gradient and was previously called "SumRank."

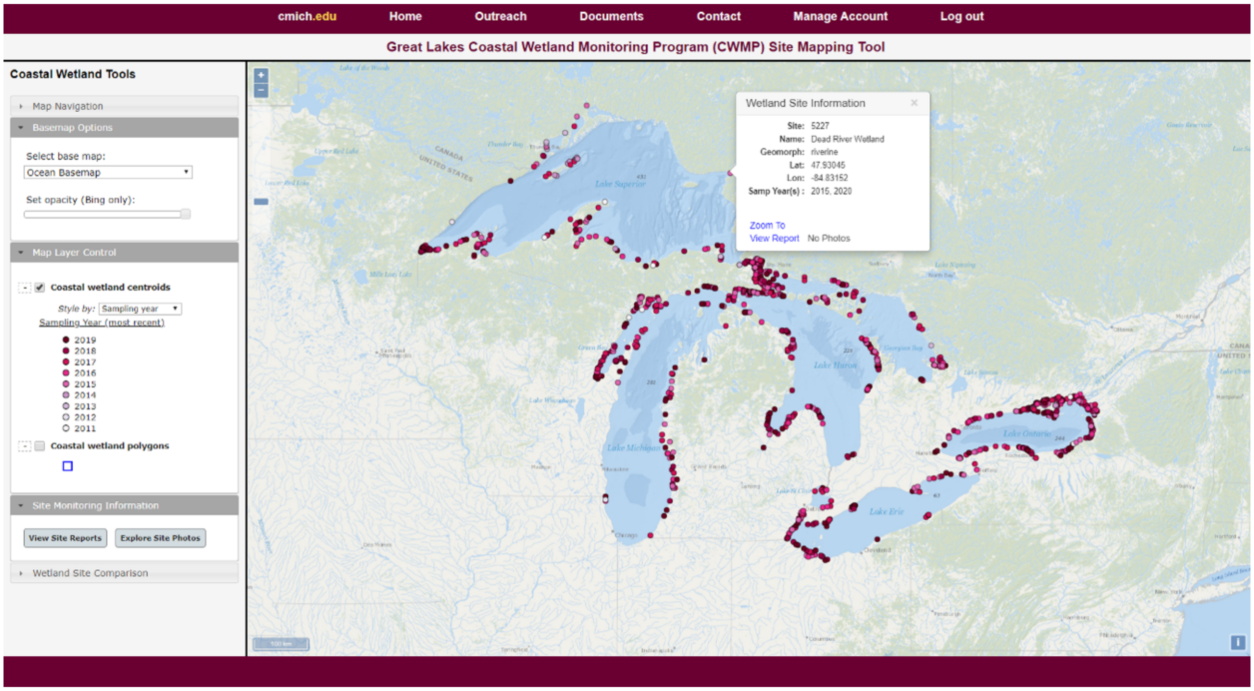

Figure 21. Coastal Wetland Mapping Tool – Public Version (sampling year view).

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

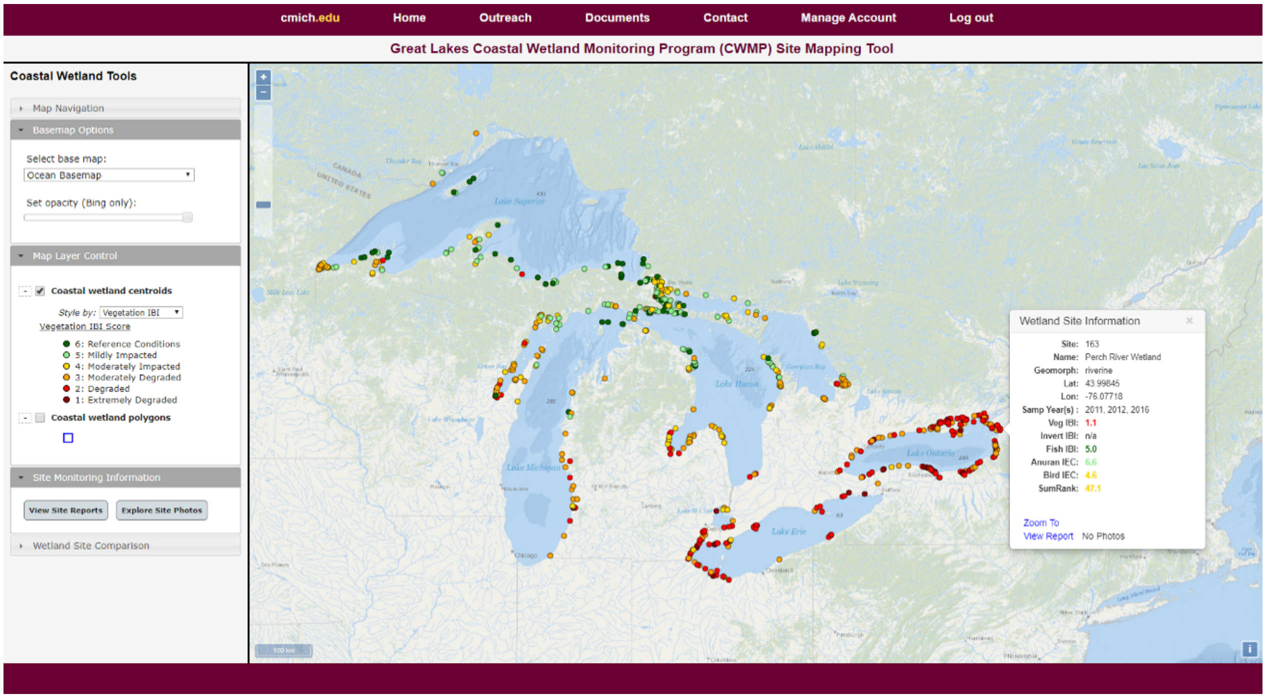

Figure 22. Coastal Wetland Mapping Tool with IBI scores displayed.

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 23), and the information can then be viewed and copied and pasted to another document, if desired.

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

- **Wetland Site Report** – a tool that provides monitoring design information, monitoring observations, and the entire matrix of IBI/IEC/Water Quality and Land Use Index scores on an individual site basis.
- **Wetland Site Photos** – a photo viewer that allows users to review CWMP-approved digital photos taken during site sampling events.
- **Wetland Site Comparison** – a tool that allows users to select a geographic area of interest on the map and then generate a matrix comparing characteristics and IBI/IEC/ Water Quality and Land Use Index scores across the selected sites.

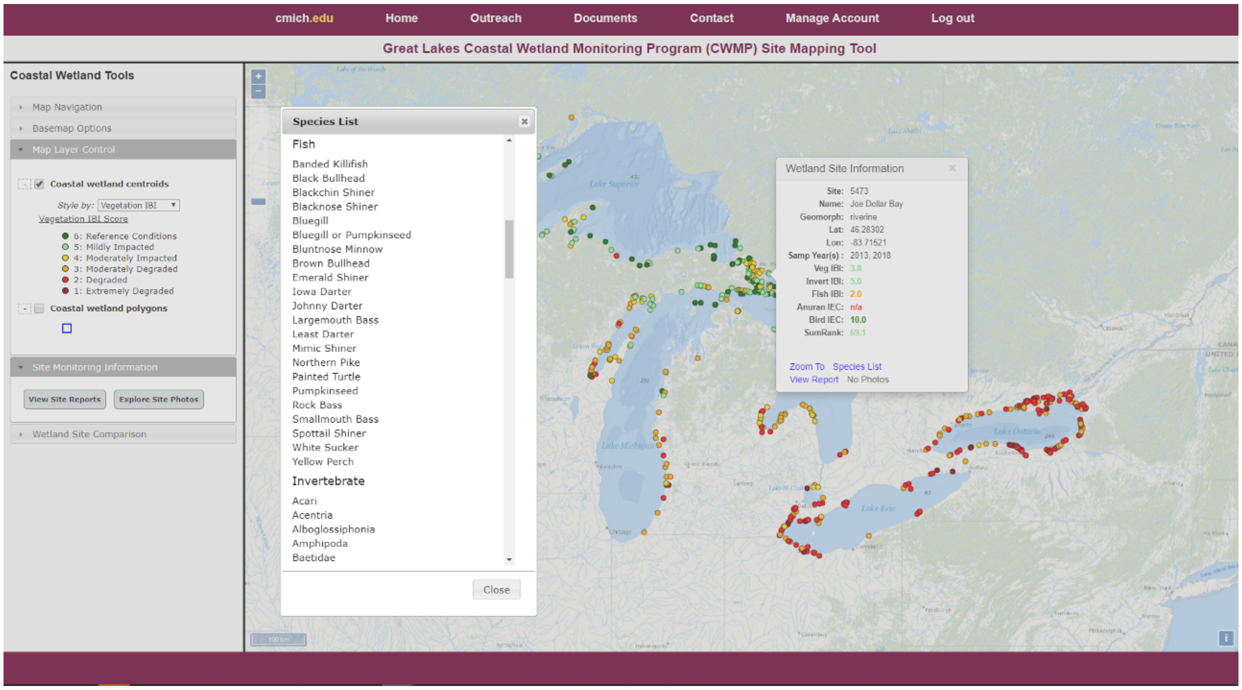

Figure 23. Coastal Wetland Mapping Tool with wetland macrophyte IBI scores and species list displayed.

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 Department of Environment, Great Lakes and Energy (EGLE) is planning to host a new webinar in 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 webinar 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 because 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 is now leading the outreach efforts for EGLE, 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 2021 there were a few VWR projects undergoing regulatory review by EGLE in which the practitioners were requested to 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 AND ANURAN TEAM, NATURAL RESOURCES RESEARCH INSTITUTE, UNIVERSITY OF MINNESOTA DULUTH

Team Members

- Dr. Annie Bracey, co-PI, avian ecologist, team lead (since 2012 as crew lead; since 2020 as co-PI
- Josh Bednar, crew leader, wildlife ecologist (10 years, since 2012)
- Nick Walton, field crew, quantitative ecologist (10 years since 2012)
- 4-5 field crew technicians

Training (updated)

Annual training for anuran surveys will be held at the Natural Resources Research Institute on April 6, 2022 and bird survey training will take place in-person May 25-26, 2022. Training involves instructing crews on how to conduct standardized field surveys, on basic travel procedures, and on appropriate field safety measures. Individuals are trained to proficiently complete field sheets and audio testing is also completed to insure that their hearing is within the normal range. Rules for site verification, safety issues including caution regarding insects (e.g., Lyme's disease), GPS and compass use, and record keeping are also included in field training to insure that the guidelines in the QAPP are being followed. All individuals involved in conducting bird and anuran surveys will have taken and passed each of the following tests on 1) anuran calls, 2) bird vocalization, and 3) bird visual identification that are based on an online system established by the University of Wisconsin, Green Bay, prior to conducting surveys – see http://www.birdercertification.org/GreatLakesCoastal.

Challenges and Lessons Learned (from fall report)

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 (updated)

In 2022, a total of 51 sites were initially selected to be surveyed for birds and anurans by the western regional team. Most of these sites have been sampled in previous years for at least one taxonomic group. All of the sites selected for sampling were reviewed to determine whether they were deemed safe and accessible to field crews. Of these 51 sites, 28 will be surveyed for anurans and 30 for birds. Sites that were excluded were for the following reasons; could not access site (*n* = 17) which included remote sites on Isle Royale which could not safely be reached by the bird and anuran team and other sites where access was not possible primarily due to private property. One site was a web reject as it did not meet sampling criteria and was not safe to access. The remaining 3 sites that were excluded for anurans were two island sites in the St. Louis River Estuary that would not be safe to survey at night by boat and one that would require access via a wastewater treatment plant that does not allow access on their property at night. Assuming travel restrictions to Canada are not reinstated, 9 of the 31 wetland sites will be surveyed by our team in Canada. Two sites are resamples from 2021 and five sites we will survey are non-panel sites (i.e. benchmark sites) occurring in the St. Louis River Estuary.

The benchmark sites were requested to be surveyed by USEPA (site 1194), WI DNR (site 1077, 1088 & 1102), and MPCA (site 7077). Each of these sites are being surveyed for either pre- or post-restoration assessments.

The location of the sites that are scheduled to be surveyed in 2022 by the bird and anuran western team stretch from the Duluth-Superior harbor area and extend eastward along the south shore of Lake Superior to the eastern end of the Upper Peninsula of Michigan as far as northeastern Lake Huron and Manitoulin Island.

Wetland Condition Observations and Results (from fall report)

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 (from fall report)

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 Findings (from fall report)

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 Reports and Findings (updated)

The bird and anuran team collectively worked through addressing all of GDIT's questions as they relate to data checks. Through this process we identified several situations that required additional clarification (e.g., 'no data' vs. 'missing data') which have now been clearly defined in the data entry system. We were also able to identify outlying data and determine whether or not it should be quarantined. We are also in the process of identifying any point count locations that have been placed in inappropriate habitat over the course of the program to ensure any locations that were in marginal habitat (e.g., woody wetland or too far from the wetland edge) are excluded from future visits.

Additional Funding and Projects (from fall report)

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 (updated)

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

Restoration of Allouez Bay, Superior, WI: In 2020, Great Lakes Audubon and the Wisconsin Department of Natural Resources put together a collaborative team to assess the restoration potential of Allouez Bay, an extensive lacustrine coastal wetland complex located in Superior, WI. This wetland has been listed as a benchmark site by CWMP since 2011 and has been sampled for birds and anurans in many of the years following. In addition to the bird and anuran data, fish and invertebrate, water quality, and vegetation data have also been collected by other CWMP teams that have sampled this wetland periodically since 2011. These data will provide critical baseline information about the quality of the site which will be used to guide restoration efforts by identifying quality from degraded habitats within the wetland site. These data will be compiled with current data being collected by WIDNR (e.g., drone aerial imagery and vegetation surveys) and Great Lakes Audubon (e.g., additional bird surveys conducted in the interior of the wetland) to model different restoration scenarios to identify which activities will be most effective in enhancing the quality of the wetland for birds and other taxa. The Phase 1 ‘planning and design’ of the project has been completed and plans are now in place to initiate Phase 2, which is on-the-ground restoration activities. We will survey this site (1077) in 2022 and beyond.

Other Data Requests (updated)

Researchers with the US EPA Great Lakes Toxicology and Ecology Division, as part of an avian indicators working group, will be implementing some of the CWMP protocols to survey birds at restoration sites throughout the Great Lakes region. They will be using Pickle Pond (CWMP site 1194) as a pilot study site to implement different survey methodologies to assess pre- and post-restoration site condition, using birds as indicators.

Related Student Research

Lisa Elliot, who is a former student of Dr. Gerald Niemi, is wrapping up revisions on a manuscript which used CWMP bird data to model habitat associations of multiple wetland obligate bird species and compare those associations to others developed in different regions (i.e. Great Lakes coastal wetlands, Great Lakes (inland wetlands), and to wetlands in the Prairie Pothole Region). Lisa is preparing to submit the manuscript to *Ecological Applications* by the end of April.

WESTERN BASIN FISH, INVERTEBRATE AND WATER QUALITY TEAM, NATURAL RESOURCES RESEARCH INSTITUTE, UNIVERSITY OF MINNESOTA DULUTH

Team Members

- Valerie Brady, PI, aquatic invertebrate and wetland ecologist (11 years, since 2011)
- Chris Filstrup, co-PI, limnologist (3 years since 2019)
- Kristi Nixon, GIS specialist (6 years since 2016)
- Josh Dumke, team leader, fisheries ecologist (11 years, since 2011)
- Kari Hansen, crew leader, fish, invertebrate, and water quality sampling (8 years, since 2014)
- Bob Hell, aquatic invertebrate and fish taxonomist (11 years, since 2011)
- Holly Wellard Kelly, aquatic invertebrate and algal taxonomist (7 years, since 2015)
- Sierra Kryzer, permanent field and lab crew member (3 years)
- Two part-time computer programmers (1 @ 6 yrs, 1 @ 1 yr)
- Two summer field techs, all new summer 2021

Training (updated for spring 2022)

The NRRI fish/invert/wq team will hold in person project training from May 30-June 3, 2022, as well as hands-on training for new summer technicians during their first site visit in Green Bay, WI (date range June 14-22, 2022). The entire NRRI team (9 participants) will be in attendance during training modules presented by permanent staff who have been working on the Coastal

Wetland Monitoring Program for >5 years. Topics covered will include: 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. The hands-on safety training will be 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) will guide 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 compared to our 2020 field season because COVID-19 vaccinations became available and travel restrictions loosened. 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.

Update: The site selection system was down for a period of time starting around December 21, 2021, until around March 4, 2022. This caused some challenges in getting the official site list for 2022, which delayed some of the prep work needed for this field season. However, the prep work has since started, and we should still be on schedule to start fieldwork on time.

Site Visit List (summer 2022)

The 2022 CWMP field season for the NRRI team consists of 28 sites. Of these 28 sites, there are 20 regular sites, 2 resample sites, 3 pre-sample sites, and 3 benchmark sites. The sites are located in Michigan counties: Alger (2), Baraga (1), Houghton (2), Keweenaw (1), Delta (4); Wisconsin counties, Ashland (1), Bayfield (1), Douglas (2), Door (3), Brown (4), Marinette (1), Oconto (1); Minnesota counties: St. Louis (1); and Canadian province: Ontario (2). Considering the COVID-19 pandemic, possible border closures may inhibit the completion of the 2 sites in

Ontario. Both of the Canadian sites are regular sites. The sites also include an island site in Door County, WI and in Alger County, MI.

The 3 Benchmark sites are located in MN and WI counties. Site 1070, Bibon Lake-Flag River Wetland, is a riverine classification in Bayfield County, WI. The NRRI team will sample a small section of the wetland that has been restored. The benchmark special request comes from the Wisconsin DNR. Site 1194, Gouge Park Pickle Ponds, is a barrier classification in Douglas County, WI that is scheduled for restoration sometime in 2022.The NRRI team will conduct pre-restoration sampling as requested by USEPA. Site 7077, SLRIDT Superfund site, is a riverine classification in St. Louis County, MN. This superfund site has been cleaned up and is being delisted. The benchmark special request comes from the AOC committee.

To efficiently divide the field sites per team, there are often trades between organizations. The NRRI team was initially assigned 20 sites for the 2022 field season. The Central Basin team was over capacity for assigned sites while NRRI had sites that were geographically closer to the Central Basin team. NRRI traded 3 sites to Central Basin, while taking on 11 of their extra sites. Thus, NRRI has 28 sites for this upcoming field season, creating a more manageable workload overall.

Panel Survey Results (from summer 2021)

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 invertebrates and water quality. The NRRI team accessed the site using inflatable Zodiak boats (Fig 24). 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 25).

Figure 24. 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 25. 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 26), 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 26. 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.

Benchmark sites

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 27), 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 27. Crew leader Bob Hell collects invertebrates around a large fyke net set in a lily zone at site 7076.

Extra Sites and Data (from fall report)

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.

Update: A few invertebrates that are new or uncommon to NRRI were collected and identified in 2021. At site 1458, Suphisselus (adult) a burrowing water beetle in the family Noteridae and Matus (adult) a predacious diving beetle were collected from the same Typha zone. This may be the first time NRRI collected either of these genera while sampling for this program. One New Zealand mud snail was collected from benchmark site 7049, it is known to be present in the SLRE but not frequently collected using our methods. Lastly the creeping water beetle Pelocoris was collected more frequently this field season. They are typically uncommon in our samples but at site 1469 they were fairly abundant and we collected 36 specimens from an SAV zone.

Data Processing (updated for spring 2022)

As of March 2022 the NRRI fish/invert/wq team has completed all data entry and QA/QC processes for field and lab data collected and analyzed for the 2021 season.

Mid-season QC Check Findings (from fall report)

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 (updated for spring 2022)

NRRI and LSSU lead taxonomists Bob Hell and Jessica Wesolek swapped unlabeled invertebrate samples as part of the annual lab identification QC procedure. Both labs completed the identification of the swapped samples and shared the results. NRRI taxonomist Bob Hell compared the taxa list and found minor differences in counts and the level of identification (family versus genus) for some taxa. This is most likely due to differing levels of experience between the two labs and their confidence separating difficult to identify invertebrate groups and smaller specimens. However, there was a consistent difference between identification of midge larvae *Chironomini/Pseudochironomi* and *Tanytarsini*. These differences are under review and were discussed by the two labs during the all lab invertebrate identification workshop held virtually on April 15th.

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 (from fall report)

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 (from fall report)

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. He will be requesting additional help with clam collection this summer from eastern basin crews.

WESTERN BASIN VEGETATION TEAM, LAKE SUPERIOR RESEARCH INSTITUTE, UNIVERSITY OF WISCONSIN SUPERIOR

Team Members

- Nicholas Danz, PI, wetland plant ecologist (11 years since 2011)
- Jeremy Hartsock, team lead, wetland plant ecologist (1 year since 2021)
- Kelly Beaster, co-crew leader, botanist (6 years since 2016)
- Read Schwarting, co-crew leader, botanist (6 years since 2016)
- Ryne Rutherford, co-crew leader, botanist (8 years since 2014)

Training (update)

Except for Jeremy Hartsock (hired Jan 7, 2021), all UWS team members have over 5-years of experience on the project and are qualified to train others. In 2022, team lead Jeremy Hartsock will again be accompanied by at least one UWS team member in the field to ensure sampling protocols are followed correctly, and to assist identifying vegetation to species level. If pre-field season trainings resume in Green Bay in 2022, UWS crew members will be present to participate.

Challenges and Lessons Learned (updated)

In 2022, COVID-19 precautions will be followed to the best of our abilities. At present, all UWS team members are fully vaccinated and boosted. Face masks will be worn by all team members while riding in vehicles and during interactions with the public. Regarding field challenges, we anticipate Lake Superior and Lake Michigan water levels will be lower in 2022, making some sites easier to navigate. Two monitoring sites are in Ontario, Canada this season. We will ensure all field crew members have updated passport information. Lastly, UWS will sample one wetland on Isle Royale; we will ensure all necessary permits are obtained and will notify the National Park Staff of our sampling plan before reaching the island.

Site Visit List (updated)

The UWS vegetation team will visit 32 sites in 2022.

Regular panel sites: 1039 - Fish Creek Wetland #1, 5210 - Cranberry Creek, 1467 - Pensaukee River Area Wetland #2, 1446 - Peats Lake Wetland #2, 1406 - Detroit Harbor Wetland #2, 1703 - Seagull Bar Area Wetland, 973 - L'Anse Bay Wetland, 1028 - Flintsteel River Wetland, 980 - Sturgeon River-Snake River Delta Wetland, 1687 - Quarry Point Area Wetland, 1457 - Long Tail Point Wetland #2, 5729 - Pine Bay 1, 1027 - Firesteel River Wetland, 999 - Lac LaBelle Wetland, 1391 - Toft Point Wetland, 5305 - Flathead Harbour, 989 - Oskar Area Wetland, 1514 - Ogontz Bay Wetland #3, 1754 - Puffy Bay Area Wetland, 942 - Grand Island Harbor Area Wetland #1, 951 - Laughing Whitefish River Wetland, 1747 - Ogontz Bay Wetland #2, 1494 - Rapid River Wetland.

Panel re-sample sites: 1441 - Point au Sable Wetland, 1456 - Long Tail Point Wetland #1, and 1076 - Poplar River Wetland.

Benchmark sites: 7049 - 21st Ave W will receive post-restoration evaluation, 1194 - Gouge Park Pickle Pond sampling was requested by EPA to evaluate restoration success, and 1077 - Allouez Bay may be surveyed depending upon time constraints.

Panel Survey Results (from fall report)

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. 28) 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 28. 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*.

Update:

Site 7077 - Kingsbury Bay is a special request benchmark site. The sampling request was made by the MPCA to determine how well restoration is proceeding.

Site 1070 - Michele Wheeler Wetland Restoration Site. The sampling request was made by the Cherie Hagan of the WDNR to determine how well restoration is proceeding.

Site 1144 - Caribou Creek on Isle Royale will be sampled for vegetation only. The site is on the CMU site visit list, but due to logistical constraints, UWS will sample the wetland for vegetation only.

Wetland Condition Observations and Results (from fall report)

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 (updated)

All vegetation data has been entered into the CWM database. QC checks were completed by Jeremy Hartsock, Ryne Rutherford, and Jenny Rutherford in November 2021.

Mid-season QC Check Findings (from fall report)

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 (updated)

CWM database manager Todd Redder reported UWS matched over 98% of GPS coordinates to vegetation sampling points. We will continue our diligent efforts to import GPS coordinates into the database and input our vegetation data immediately following the end of field sampling.

Additional Funding and Projects (updated)

In addition to CWM work in 2022, we plan to survey several sites (final site list is not currently available) in the St. Louis River Estuary for aquatic macrophytes for the Minnesota Pollution Control Agency (MPCA). The 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.

Figure 29. Baird's Sandpiper at site 7048 (benchmark 40th Ave West site, Duluth, MN). Photograph by Jeremy Hartsock.

Other Collaboration Activities (updated)

We have continued to rely on contractor botanist Ryne Rutherford to assist with our vegetation sampling at Green Bay and Upper Peninsula CWM sites. In February, we submitted a manuscript with Ryne as first author to the journal Wetlands Ecology and Management. The manuscript discusses plant community responses to water level fluctuation at Oconto Marsh #2, a CWM site in Green Bay, WI.

Other Data Requests (updated)

In Fall 2021, 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. No data requests have been made for 2022.

Related Student Research

N/A

CENTRAL BASIN BIRD AND ANURAN TEAM, UNIVERSITY OF WISCONSIN-GREEN BAY

Team Members

- Dr. Robert Howe, PI (since 2011)
- Erin Giese, team leader (since 2012)
- Field crew Brenna Nicholson, Josh Dietzler, Mabel Kirst, Haley Spargur, Brandon Byrne, Jacob Woulf

Training (updated)

The 2022 CWMP training began in February and will continue through May 2022 at the University of Wisconsin-Green Bay. In March 2022 Haley Spargur passed the anuran certification test and will be trained on conducting anuran surveys in the field in April-May 2022. Since February 2022, team Leader Erin Giese has been training Mabel Kirst and Josh Dietzler on bird identification. These students will take bird certification tests in May 2022. In March 2022, Giese hosted an office training with all team members to review the CWMP, sites to be sampled, field scouting, conducting anuran surveys, filling out data forms, GPS naming, safety, etc. Returning crew member Brenna Nicholson trained the new team members on GPS use, navigation, and other field equipment (e.g., water thermometer) in April 2022. Field training will continue until Giese has determined that all new members are following protocols, using equipment correctly, and capable of acquiring accurate information. Training materials are available upon request from giesee@uwgb.edu. 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 (from fall report)

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 (updated)

We were assigned 47 sites to be surveyed in 2022, in which 13 are in Wisconsin (including 1 ferry site, 4 boat/kayak sites), 7 Rapid River, MI (including 3 boat/kayak sites), and 27 in Cedarville, MI (including 3 ferry sites and at least 8 boat/kayak sites). Of the 47 sites assigned to our team, 5 are re-sample sites, 4 are pre-sample sites, and 1 is a benchmark site (site 7055 was assigned as a benchmark site for all crews because it has never been sampled by any teams over the past decade).

We anticipate not being able to survey 10-15 panel sites due to access-related reasons, such as 1) no road access, 2) remote island, or 3) private land for which we may not connect with a land owner, though we have not scouted or surveyed any sites yet (April 2022).

Panel Survey Results (from fall report)

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 (from fall report)

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 (from fall report)

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 were double entered by field crew members and cross checked for QA/QC before this reporting period.

Mid-season QC Check Findings (from fall report)

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 (from fall report)

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 (from fall report)

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 (updated)

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.

In April 2022 Team Leader Erin Giese submitted 2021 anuran and bird species lists for site 1678 to the Wisconsin Department of Natural Resources (WDNR) who granted access to this site in 2021, which is located on a State Natural Area. Giese also provided 2021 anuran and bird species lists for site 1681 to the WDNR and The Nature Conservancy for providing access to their property in 2021, which is also located on a State Natural Area.

Related Student Research (from fall report)

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 BASIN BIRD AND ANURAN TEAM, CENTRAL MICHIGAN UNIVERSITY

Team Members

- Thomas Gehring, PI, wildlife and landscape ecologist (11 years since 2011)
- Bridget Wheelock, crew leader, (10 years since 2012)
- Megan Bos, graduate student crew leader (1 year since 2021)
- Megan Casler, graduate student crew leader (new spring 2022)
- Two undergraduate student technicians (new spring 2022)

Training (updated)

Anuran training was completed 23 March 2022 and bird training is planned for early May (before 15th May, 2022). Online testing was used for identification of anurans by sound and birds by sight and sound. All data collectors will have reached proficiency before sampling.

All individuals involved in conducting the surveys will pass 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.

Update

A total of 43 sites have been assigned to the CMU bird and anuran crews for the 2022 field season. Of those sites 34 are panel year sites, 5 are resample sites from the 2021 field season and 4 are benchmark sites. The benchmark sites are Indian Harbor Wetland (7061), East Saginaw Bay Coastal Wetland #5 (515), Point St. Ignace Wetland (1598) and Shiawassee Flats (7075). All were requested by Dr. Don Uzarski except Shiawassee Flats; 7061 represents low disturbance, 515 represents high disturbance, and 1598 is being monitored due to potential environmental changes in the Straits of Mackinac. Site 7075 was requested as a benchmark by the United States Geological Survey (USGS) to monitor restoration progress.

Panel Survey Results (from fall report)

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 (from fall report)

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.

Wetland Condition Observations and Results

N/A

Data Processing (from fall report)

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 (from fall report)

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 (from fall report)

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

CENTRAL BASIN FISH, INVERTEBRATE AND WATER QUALITY GROUPS (CENTRAL MICHIGAN UNIVERSITY, GRAND VALLEY STATE UNIVERSITY, LAKE SUPERIOR STATE UNIVERSITY, UNIVERSITY OF NOTRE DAME)

Team Members

- Dr. Donald Uzarski (CMU), lead-PI, wetland ecologist (11 years since 2011)
- Bridget Wheelock (CMU), crew leader, fish, invertebrate, and water quality sampling (10 years since 2012)
- Molly Gordon (CMU), aquatic invertebrate taxonomist (11 years since 2011)
- Sarah Longuski, Marta Kendziorski, Aiden Judge (CMU), summer field technicians (all new summer 2022)
- Christie Cromar (CMU), summer lab technician (new summer 2022)
- Dr. Carl Ruetz (GVSU), PI, fisheries biologist (12 years since 2010)
- Matthew Silverhart (GVSU), crew leader, fish, invertebrate, and water quality sampling, QC manager, graduate assistant (2 years since 2020)
- Collin Assenmacher (GVSU), summer field technician (new summer 2022)
- Sunny Charpentier (GVSU), summer field technician (new summer 2022)
- Dr. Ashley Moerke (LSSU), PI, (11 years since 2011)
- Jessica Wesolek (LSSU), crew leader and invertebrate taxonomist
- Avery Feldmeier and Savannah Blower (LSSU), returning summer field technicians
- Michael Hillary (LSSU), summer field technician (new summer 2022)
- Dr. Gary Lamberti (UND), PI, (11 years since 2011)
- Sarah Klepinger (UND), crew leader, invertebrate taxonomist, lab manager (3 years since 2019)
- Drs. Katherine O’Reilly and Daniele Del Almeida Miranda (UND), post-docs, field technicians
- Alison Zachritz (UND), graduate student, field technician
- Two summer technicians (UND; new summer 2022)

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.

Update

Central Michigan University will be hosting the Central Basin fish/invertebrate/water quality training at site 515 in Saginaw Bay on 14 June 2022 and 15 June 2022. The training will be led by CMU crew leader Bridget Wheelock who has been part of the CWMP since 2012. The topics covered will be water quality collection (*in situ* data collection, filtering, and titration), GPS navigation, site/zone selection, invertebrate sampling and picking, setting and retrieving fyke nets, and fish handling. The GVSU crew will supply and use their own equipment to familiarize themselves with the equipment. The training will be attended by crew leader Matthew Silverhart (certified in 2021 field season) and two new summer field technicians (to be certified during training).

The LSSU hiring process for summer 2022 crews was completed in early March and Michael Hillary will be returning to lead the LSSU crew, along with Jesse Wesolek, who will remain the invertebrate taxonomist for our program. Jacob Fenner and Brendan Petts, two Fisheries and Wildlife Management undergraduates will assist Michael in sampling. Moerke attended the annual meeting on 4 February 2022 and the fish taxonomy workgroup on 18 February 22. Initial training for 2022 sampling, led by PI Moerke, will begin 1 June 2022, followed by the Central Basin training. The LSSU crew will participate in both trainings to ensure that protocols implemented by LSSU align with the US Central Basin team. Sarah Klepinger, Katherine O'Reilly and Alison Zachritz of UND are trained and experienced in CWMP protocols. Any undergraduate technicians will be trained immediately after they are hired.

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.

<u>Update</u>

It has previously been a challenge to access Canadian sites from the US side, but restrictions appear to be lifting this spring.

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).

<u>Update</u>

A total of 58 sites have been assigned to the Central Basin fish/invertebrate/water quality crews for the 2022 field season. Of those sites 45 are panel year sites, 7 are resample sites from the 2021 field season and 6 are benchmark sites. The benchmark sites are Tobin Harbor Creek Wetland (1131), Moskey Basin Campground Wetland (1136), Indian Harbor Wetland (7061), East Saginaw Bay Coastal Wetland #5 (515), Point St. Ignace Wetland (1598) and Shiawassee Flats (7075). All were requested by Dr. Don Uzarski except Shiawassee Flats; 1131, 1136 and 7061 represents low disturbance, 515 represents high disturbance, and 1598 is being monitored due to potential environmental changes in the Straits of Mackinac. Site 7075 was requested as a benchmark by the United States Geological Survey (USGS) to monitor restoration progress.

Central Michigan University was assigned 26 sites for the 2022 season (536, 537, 538, 541, 547, 549, 590, 597, 615, 616, 637, 649, 744, 776, 778, 780, 862, 1125, 1130, 1131, 1136, 1144, 1584, 1598, 1805 and 7061). For the 2022 field season the GVSU crew was assigned 12 sites (455, 459, 460, 461, 515, 517, 520, 1281, 1303, 1304, 1307, and 7075). Their plan is to assess and sample all sites assigned to the GVSU crew. The GVSU crew has set aside 6 weeks to sample assigned sites. Those weeks are 13 – 17 June, 24 June – 1 July, 11 – 15 July, 1 – 5 August, 8 – 12 August, and 22 – 26 August. The LSSU crew was assigned 12 sites for the 2022 season (837, 793, 796, 804, 807, 808, 869, 878, 901, 915, 926, and 7055). The UND crew plans to sample sites 1903, 1913, 1928, 432, 434, 435, 1651 and 1313 for fish, invertebrates and water quality.

Panel Survey Results (from fall report)

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.

Non-native Species by Site

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*

Site	Common Name	Taxa name
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 (from fall report)

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 (from fall report)

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 (updated)

All habitat, fyke, water quality and *in situ* field data have been entered and QA'd for all crews. Chlorophyll-a samples have been analyzed, entered and QA'd for all crews. Macroinvertebrate identification has been completed by the LSSU and UND labs. The CMU lab is still finishing up macroinvertebrate IDs from the CMU and GVSU 2021 sites. 91% of the initial macroinvertebrate ID's have been completed and 51% of the macroinvertebrate samples have been QA'd, entered into the database and QA'd in the databased. Sample processing is expected to be finished by May of 2022. When all macroinvertebrates are identified we will trade samples with our collaborating QA laboratory. Macroinvertebrate sample exchanges between LSSU and NRRI for QC were also completed.

Mid-season QC Check Findings (updated)

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 2021 mid-season QC check occurred on July 21 at site 1301 (Pentwater River Wetland). This site had mats of thick European frogbit, which made setting nets difficult.

Additionally, predator activity posed a problem. Herons and muskrats tore numerous holes in our nets, which likely released fish and lowered our fish count to below the minimum 10 per zone. The decision was made not to re-set the nets, because the outcome was likely to be the same and we did not want to subject our nets to further damage. Our PI, Gary Lamberti, accompanied us and approved this decision.

Audit and QC Report and Findings (updated)

In December, a QC review found questionable entries for fyke net set times. One entry was a missed number (wrong date) and the others were not entered in the 24-hour format. All entries were corrected and checked in the database within a week.

Additional Funding and Projects (from fall report)

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.

<u>Update</u>

Ashley Moerke is on the planning team for the upcoming Coastal Wetlands Symposium meeting to be held in Sault Sainte Marie, MI in September 2022.

The Lamberti Lab is collaborating with the Peaslee lab at the University of Notre Dame on a project involving per- and polyfluoroalkyl Substances (PFAS) in fish populations. This did not involve any CWMP data or funding in 2021.

Other Data Requests (updated)

GVSU graduate assistant research project described below.

University of Michigan-Flint graduate student requested benchmark site 7075 water quality and biotic data (all years) for comparison with the Flint River.

Joseph Gentine (a Lamberti Lab undergraduate student) requested and was granted access to the CWMP database to help with his senior thesis, which is also a manuscript that was recently accepted by the Journal of Great Lakes Research.

Joseph Gentine and Samuel Bosio (another Lamberti Lab undergraduate student), have also requested and been given access to the CWMP database and have used Anuran and invasive plant data from it.

Dr. Matt Cooper used macroinvertebrate data from several Lake Michigan wetlands as reference sites to compare two restoration sites in the Muskegon Lake Area of Concern. This analysis is being used to evaluate the *Degradation of Benthos* Beneficial Use Impairment (BUI) for the AOC.

Related Student Research (updated)

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.

Matthew Silverhart, a graduate student at GVSU, has received permission from the collaborating institutions on the GLCWMP to use the fish data collected across the project to evaluate spatial patterns of fish communities in Great Lakes coastal wetlands for his master's thesis.

Three LSSU undergraduates conducted their senior thesis research on projects related to GLCWMP. One (Savannah Blower) was evaluating macroinvertebrate assemblages between hardened and natural shorelines. Savannah recently presented a poster at the MI American Fisheries Society annual meeting and was awarded the Best Student Poster award. Savannah also presented her poster virtually at the Midwest Fish and Wildlife Conference and she was awarded a student travel award. A second student (Michael Hillary) is quantifying litter decomposition and respiration rates in wetlands of varying health. Michael is also collaborating with Dr. Matt Cooper. Michael also presented his poster this January at the Midwest Fish and Wildlife Conference and at the MI American Fisheries Society meeting in March. Michael also was awarded a LSSU Undergraduate Research Fund award to support his research. A third student (Avery Feldmeier) is evaluating fish assemblage changes throughout a summer in three St. Marys River coastal embayment wetlands. Avery also presented his poster at the MI American Fisheries Society meeting this March.

Joseph Gentine's senior project "Environmental Predictors of Algal Chlorophyll-a in Great Lakes Coastal Wetlands" has several CWMP co-authors. He used chlorophyll-a measurements from 514 wetlands across all the lakes to determine how mean concentrations varied between lakes. He developed two random forest models to predict chlorophyll-a concentrations for each lake– one using variables that may directly relate to phytoplankton biomass and another using variables with potentially indirect effects on phytoplankton growth.

Samuel Bosio and Joseph Gentine pulled Anuran and invasive plant data from the CWMP database to look at relationships between the two.

CENTRAL BASIN VEGETATION TEAM, CENTRAL MICHIGAN UNIVERSITY

Team Members

- Dr. Dennis Albert, PI, wetland vegetation ecologist/botanist (11 years since 2011)
- Allison Kneisel, team leader, wetland plants and invertebrates (7 years since 2011)
- Matthew Sand, crew leader, wetland plants and water chemistry (4 years since 2017).
- One academic year tech (1 year since 2021).

Training (mostly from fall report)

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.

Update

Allison Kneisel will lead a training on the sampling protocol in mid-June and Dr. Dennis Albert will lead the plant identification training in late June for the 2022 field season.

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.

Update

During the annual spring meeting, vegetation crews discussed how to handle mixed and patchy zones and who to contact when questions arise.

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).

Update

57 sites have been assigned the central basin vegetation crew for the 2022 field season. Of those sites 47 are panel year sites, 7 are resample sites from the 2021 field season and 3 are

benchmark sites. The benchmark sites are Indian Harbor Wetland (7061), East Saginaw Bay Coastal Wetland #5 (515), and Point St. Ignace Wetland (1598). All were requested by Dr. Don Uzarski; 7061 represent low disturbance, 515 represents high disturbance, and 1598 is being monitored due to potential environmental changes in the Straits of Mackinac.

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.

Update

Epoufette Bay Wetland #1 (1586), Lake George West Shore Wetland #1 (816), and Temperance Island Wetland (1604) all had high species richness, with 68, 67, and 66 taxa respectively. This was also the first year that Temperance Island Wetland could be sampled as weather often makes the boat trip to this site difficult. Bar Lake Wetland #1 (1280) was also sampled for the first time this year and contained the relatively rare species *Berula erecta*.

Common invasive species including *Hydrocharis morsus-ranae*, *Lythrum Salicaria*, *Myriophyllum spicatum*, *Phragmites australis*, *Typha angustifolia*, and *Typha glauca* were found across the central basin area, with no obvious expansion of range.

Invasive species found in central basin sites:

Invasive Species	Sites
Acorus calamus	767, 802, 816, 1325, 1598
Agrostis gigantea	536, 806
Butomus umbellatus	1904
Centaurea stoebe	539
Cirsium arvense	906, 1904
Frangula alnus	536
Hydrocharis morsus-ranae	802, 816, 1301, 1898, 1904, 1933
Linaria vulgaris	539, 1604
Lysimachia nummularia	590
Lythrum salicaria	536, 786, 802, 816, 906, 1546, 1604, 1904
Myriophyllum spicatum	466, 494, 510, 1301, 1305, 1586, 1598, 1898, 1904, 1933

Persicaria lapathifolia	1546
Persicaria maculosa	816, 1598
Phalaris arundinacea	554, 590, 613, 619, 660, 802, 906, 917, 1267, 1301, 1586, 1904
Phragmites australis	466, 494, 510, 515, 548, 1898, 1904
Poa compressa	548, 1598, 1604
Potamogeton crispus	494,1301, 1305, 1325, 1898, 1904
Typha angustifolia	494, 536, 590, 767, 778, 802, 1598, 1933
Typha glauca	590, 613, 619, 660, 778, 802, 1301, 1305, 1325, 1586, 1598

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.

<u>Update</u>

Hughes Point Wetland (1546) was the most diverse site sampled in the central basin with 71 taxa. Even though the meadow zone, where most of the plant diversity is found, was much narrower than in 2013, when it was first sampled, the diversity remains quite high.

The data for all these sites has been entered into the data management system.

Wetland Condition Observations and Results (from fall report)

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 (updated)

All data has been entered at greatlakeswetlands.org by Kendalyn Town and Matthew Sand and has been quality checked by PI Denny Albert.

Mid-season QC Check Findings (from fall report)

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 (updated)

All data has been reviewed by Dr. Albert. No major quality issues have identified since fall 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.

Other Data Requests

There are no vegetation data requests to report.

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. She has begun hierarchical modeling to determine if water levels and other wetland characteristics impact wetland land extent.

CENTRAL/EASTERN BASIN BIRD AND ANURAN TEAM, BIRDS CANADA

Team Members

- Doug Tozer, PI, waterbird and anuran ecologist (12 years since 2011)
- Jeremy Bensette, bird and anuran field crew (9 years since 2014)
- Tim Arthur, bird and anuran field crew (6 years since 2017)
- Tyler Hoar, bird and anuran contractor (12 years since 2011)
- Nadine Litwin, bird and anuran contractor (12 years since 2011)

Training (updated)

All four field crew members / contractors will receive training refreshers via Zoom or phone in early April 2022. Topics will include 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 (updated)

Field work in 2022 looks like it will be much less restricted by COVID-19 compared to the past two years. Currently there are few public health regulations in place in Ontario so we anticipate a much smoother operation during spring and summer 2022. This includes, for the first time since 2020, a bird and anuran team from the US that will likely be able to cross the border into northern Ontario and survey a number of sites between Sault Ste. Marie and Manitoulin Island on Lake Huron, which is the way we normally handle getting sites surveyed in that area. This, of course, was not possible in 2020 or 2021 due to COVID-19 border-crossing challenges. We have been able to get many of these sites surveyed ourselves by "piggy-backing" on funds and efforts of other projects (e.g., Ontario Breeding Bird Atlas-3), but this is not something we will be able to sustain. Hopefully international border crossings will be smooth for 2022 and in future years as well.

Site Visit List (updated)

We are considering 56 sites for sampling in 2022, which consist of 49 panel, 5 resample, and 2 special-request benchmark sites. We will attempt to survey 40 of these 56 sites. We are unable to survey 16 of the sites due to the following:

- lack of connection to the main lake (2 sites)
- issues with obtaining landowner access, including complications due to COVID-19 (4 sites)

- safety (10 sites)

Panel Survey Results (from fall report)

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).

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 (from fall report)

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 (from fall report)

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 (updated)

All of of our data has been entered into and checked in the CWMP database.

Mid-season QC Check Findings (from fall report)

Mid-season checks were performed in mid-June, 2021; no issues were identified.

Audit and QC Report and Findings

No issues to report.

Additional Funding and Projects (updated)

We are exploring possible sources of additional funding to augment the bird and anuran team's capacity to complete a bird (and possibly also anuran) 10-year trend analysis using all of the CWMP data in Canada and the US. This possible project is described further in the next section.

Other Collaboration Activities (updated)

The CWMP bird and anuran team will very likely collaborate with Danielle Ethier, the Bird Population Scientist at Birds Canada in Port Rowan, Ontario, to complete a bird (and possibly also anuran) 10-year trend analysis using all of the CWMP data in Canada and the US. The project will likely generate population trends for a large suite of bird (and possible also anuran) species in different catchments relevant to conservation and management, such as Great Lakes (Superior, Michigan-Huron, Erie, Ontario), states/provinces, bird conservation regions, wetland types (lacustrine, riverine, barrier-protected), and within AOCs versus outside, etc.

Other Data Requests

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

Related Student Research (updated)

We provided advice and guidance to Megan Casler, a MSc student at Central Michigan University, under the supervision of Tom Gehring. Megan plans to use CWMP data to test whether and how much the addition of invertebrate and water quality covariates improve bird habitat relationship models based on vegetation and land cover covariates.

CENTRAL/EASTERN BASIN FISH, INVERTEBRATE AND WATER QUALITY GROUP (UNIVERSITY OF WINDSOR, UNIVERSITY OF WISCONSIN RIVER FALLS)

Team Members

Principal Investigators:	Jan Ciborowski, Paul Weidman (UWindsor) Joseph Gathman (UW River Falls)
Permanent staff:	UWindsor – Li Wang, Michelle Dobrin, Stephanie Johnson, Anique Gauvin, Emilee Mancini

Training (updated)

The individuals who will participate in fieldwork in 2022 were involved in sampling during the 2021 and earlier field seasons. Consequently, only refresher training will be undertaken for them.

Field crew members working with fishes, macroinvertebrates, and water quality sampling will receive refresher orientation during May 2022 and are expected to conduct pilot sampling at local sites on Lake Erie during late May and early June. With relaxation of restrictions on international travel, the UWindsor team will resume sampling sites in western Ohio. All members of the 5-person Windsor field crew from 2021 will be involved in field work in 2022 (including vegetation lead Carla Huebert). They will train 1-2 new senior undergraduate students and orient new coinvestigator Paul Weidman, who will assist during selected field trips.

Training review will include GPS use, determination of whether sites meet project criteria (open water connection to lake, presence of a wetland, safe access for crew), identification of vegetation zones to be sampled, collection of water quality samples (including preprocessing for shipment to water quality labs) and calibrating and reading field instruments and meters. Other review will include refresher instructions in setting, removing, cleaning and transporting fyke nets, and special emphasis on collecting voucher information (proper photographic procedures, collection of fin clips for DNA analysis, or retention of specimens for lab verification of identity), protocols for collecting and preserving macroinvertebrates using D-frame dip nets and field-picking. All crew members will review field data sheet entry procedures, including changes to the data sheets implemented since last field season and first-hand data-entry responsibilities after field trips. All field personnel will be given refreshers in basic fish identification training.

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

All field team members have taken the Royal Ontario Museum course in fish identification, which is required of at least one team member in possession of an Ontario Scientific license to collect fishes. Team members will receive refreshers in field and lab safety training.

Challenges and Lessons Learned (from fall report)

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 (updated)

New sites for 2022 have been assessed by remote examination. Preliminary assessments of site accessibility and suitability for sampling that we may perform for other teams is also complete. Correspondence is underway with landowners and First Nations to facilitate access to sites on their properties designated for surveys in 2022. However, given the continuing risks of COVID 19 transmission, we expect that our requests for access to First Nations lands will be denied.

Sampling for fishes in Canada requires approval by the University of Windsor's Animal Use Care Committee as well as permits for Scientific Collection of Aquatic Species (Ontario Ministry of Natural Resources), compliance with the Province of Ontario's Environmental Protection Act (Ontario Ministry of Natural Resources), and Species At Risk (Fisheries & Oceans Canada). Fish sampling on the Ohio shores of Lake Erie requires a Wild Animal Collection permit (Ohio Department of Natural Resources), and sampling in National Wildlife Refuges in Ohio requires permits from the UW Fish and Wildlife Service. Permit renewal applications are in progress to ensure approval by the start of the sampling season. Reports to the permit granting agencies for 2021 collections have been submitted. Detailed records of fishes caught were sent to local conservation and refuge managerial groups in Ontario and Ohio where appropriate.

Panel Survey Results/ Extra Sites and Data - *Benchmark sites* (from fall report)

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 (from fall report)

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 (from fall report)

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 (updated)

All field data collected during the 2021 field season have been uploaded and QA'd. Specimens are being exchanged with one of the two companion labs (part of the reciprocal exchange of macroinvertebrate specimens to ensure consistency of identification). Samples received in previous years have been identified and returned to the sample owners.

Mid-season QC Check Findings (from fall report)

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 (from fall report)

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

Nothing to report

Other Collaboration Activities and Collaborations (updated)

We have been building a multi-year working relationship with Point Pelee National Park (PPNP). In 2020, we attempted to sample Lake Pond in PPNP to provide Park personnel with additional pre-restoration baseline information relating to the implementation of a vegetation-removal exercise meant to reduce *Phragmites* and *Typha* encroachment and improve hydrological connectivity among several connected waterbodies. This work is also helping to identify the changes that have occurred as the result of a breach in the protective sand-spit cause by high lake levels. The breach created in summer 2018 between Lake Pond and the east shore of Lake Erie continued to permit water exchanges and contributed to continuing high water levels. We will extend our sampling to include West Cranberry Pond), as requested by the PPNP staff. We will also sample nearby Hillman Marsh, which is under the jurisdiction of PPNP. Both Point Pelee and Hillman Marsh are designated as benchmark sites for 2022.

In 2020, we conducted detailed analysis of CWM information in collaboration with the Detroit River Canadian Cleanup (DRCC) group (responsible for Canadian waters of the Detroit River Area of Concern): CWMP data on fishes, aquatic invertebrates, vegetation and water quality were combined with other data collected by various consortia to determine criteria by which to delist several Beneficial Use Impairments. Using CWMP information from all available sites on

Lake Erie and in the St. Clair-Detroit River system, were able to identify benchmarks in biological condition that have been adopted by the DRCC to assess Impaired Beneficial Uses #2 (Macroinvertebrates), #3 (fishes) and #14 (Aquatic Habitat). We found that bird IEC as well as IBI scores are informative in assessing thresholds in the amount of agricultural vs. developed land in watersheds. We also identified fish and invertebrate IBI index benchmarks. However, they reflected local water quality independently of habitat condition *per se* (Ciborowski et al. 2020).

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

Other Data Requests (from fall report)

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 (from fall report)

One student completed his M.Sc. thesis spring 2021:

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) fall 2021 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.

Related Research in Progress (new)

In 2015 and 2016, fish data were analysed by then graduate student Jeffrey Buckley (M.Sc. 2015) to compare the consistency of classification of wetland condition using analytical metrics derived by several different investigators. Buckley compared the newly revised wetland IBI of Cooper et al. (2018) with the fish quality indices of Seilheimer et al., and a new multivariate index (Fish Assemblage Condition Index [FACI]), based on the reference-degraded continuum approach (Bhagat et al. in prep.). The Cooper et al. and Seilheimer et al. and FACI indices all exhibit high degrees of sensitivity and specificity to degradation by anthropogenic stress when used to assess the sites from which data were originally gathered. The indices' ability to accurately assess the condition of sites sampled over the past few years is somewhat reduced but still considered to be acceptable. This MS will be submitted in 2022.

Danielle Gunsch (M.Sc. 2020) estimated diel dissolved oxygen cycles and the associated invertebrate and fish fauna along an elevation/depth gradient within the wet meadow zone of 10 Lake Huron wetlands (5 reference wetlands and 5 draining agricultural watersheds). The duration of hypoxia (DO concentrations <4 mg/L) ranged from as much as 20 h per day in shallow (30-cm deep) locations to as little as 4 h in deeper water. Wetlands adjacent to agricultural lands exhibited greater daytime supersaturation than paired reference sites draining woodland. However, sieche effects often reversed expected day/night patterns. Differences in the abundance of the most commonly encountered large invertebrates were greater between regions (North Channel of Georgian Bay vs. Bruce Peninsula wetlands) than along the elevation/depth gradient within each wetland. Significant differences in abundance of some taxa (coenagrionid damselflies, *Gammarus* and *Hyalella* amphipods, and flatworms) were observed along transects, particularly in North Channel wetlands. Nevertheless, multivariate analyses of community composition indicated that differences among wetlands were much greater than differences among locations along transects within wetlands. Ultimately, this research is expected to provide new fish and benthic invertebrate measures sensitive to the effects of agricultural activity in wet meadow regions of wetlands.

During the summer of 2020, Stephanie Johnson continued a project to survey zooplankton (Cladocera, Copepoda, Rotifera) communities of selected coastal wetlands. Sample processing is continuing, resulting in species lists occurring in selected microhabitats. This work is important because very little work has been published on the microcrustacean/meiofauna communities of coastal wetlands.

In 2020, we continued to assess day-night variability in wetland dissolved oxygen, temperature and water levels to determine the influence that these variables may be having on samples of aquatic invertebrates and catches of fishes in fyke nets. We deployed Onset Hobo water level loggers within wetland sites during the time that fyke nets were in place. Colleagues from other CWMP teams also contributed data from selected sampling efforts. We also installed one or more Onset Hobo dissolved oxygen (DO) loggers and light temperature recorders at the location of each fyke net in each wetland for the 18-24 h, corresponding to the duration of fyke net sets.

Water level loggers were deployed at 37 sites by 3 CWMP teams during their fish sampling periods in 2020. Dissolved oxygen records were collected for 26 of those sample series. The data are expected to yield improved understanding of the factors contributing to variability in fish catches, and help define the environmental suitability of areas for mobile fishes and the likelihood of capturing them.

In supplemental work, Nathan Tuck (M.Sc. 2021) analysed data from fyke net catches and water-level and dissolved-oxygen loggers deployed in two Lake Erie wetlands over much of the sampling season. Fyke nets captured fish during both seiche and calm weather periods in each wetland to estimate the importance of seiches on fish abundance and community composition estimates. Wind action dramatically influences water quality parameters - particularly temperature and dissolved oxygen concentrations. Even in the absence of significant seiches, daytime winds brought cool, normoxic water into the wetland whereas night-time calm periods resulted in rapid anoxia as water flowed from shallow, emergent areas into the main wetland. In one small wetland, onshore wind drove oxygen-rich lake water into the wetland allowing immigration (and fyke net captures) of large, lake-dwelling fishes. When these events were followed by hot, calm nights, water became anoxic and resulted in significant overnight mortality of trapped fishes. In contrast, the larger water volume of a riverine wetland largely dampened the effects of seiches on changes in dissolved oxygen concentration and fish catches.

CENTRAL/EASTERN BASIN VEGETATION GROUP (UNIVERSITY OF WINDSOR, UNIVERSITY OF WISCONSIN RIVER FALLS)

Team Members

- Jan Ciborowski, PI, aquatic ecologist (11 years since 2011)
- Joseph Gathman, co-PI, aquatic ecologist (11 years since 2011)

- Paul Weidman, co-PI, limnologist (2 years since 2020)
- Li Wang, Data Management leader (11 years since 2011
- Carla Huebert, Vegetation field lead and taxonomist (8 years since 2011)
- Stephanie Johnson, permanent field and lab crew member (5 years)
- Emilee Mancini, permanent field and lab crew member (3 years)
- Anique Gauvin, field crew member (3 years)

Training

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

During May 2022 we expect to conduct pilot sampling at local sites on Lake Erie during late May and early June. With relaxation of restrictions on international travel, the UWindsor team will resume sampling sites in western Ohio. All members of the 5-person Windsor field crew from 2021 will be involved in field work in 2022. They will train 1-2 new senior undergraduate students and orient new coinvestigator Paul Weidman, who will assist during selected field trips. Other review will include special emphasis on collecting voucher information. All crew members will review field data sheet entry procedures, including changes to the data sheets implemented since last field season and first-hand data-entry responsibilities after field trips.

Challenges and Lessons Learned (from fall report with update)

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.

Update

Despite anticipated easing of high-water conditions on Lake Erie and Lake Huron, we will, where necessary, use the sampling guidelines that we implemented in 2020 and 2021. All crew are fully trained in both these new guidelines and in the revisions outlined in the 2021 QAPP. As in 2020 and 2021, we will sample SAV zones, but only when there are no other zones to sample.

Site Visit List (updated)

We anticipate sampling 33 sites during the 2022 field season (Table 1), three of which are benchmark sites (5762 (Point Pelee Marsh 2), 5999 (Turkey Creek Marsh), and a third site (to be determined) representing minimally stressed environmental conditions.

Panel Survey Results/ Extra Sites and Data - *Benchmark sites* (updated)

As in previous years, Point Pelee Marsh 2 will be 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, reducing the extent of fish habitat including habitat for several Species-at-Risk. In addition, Turkey Creek Marsh will be sampled to provide current information on the distribution of water lettuce, which was first observed there last year.

Extra Sites and Data

None.

Wetland Condition Observations and Results Significant Observations (from fall report)

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.

<u>Swamp Rose Mallow (*Hibiscus moscheutos*)</u> 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 30). 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.

Starry Stonewort (*Nitellopsis obtusa*): 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).

Figure 30. Water Lettuce (*Pistia stratiotes*) found for the first time at Site 5999, Turkey Creek, Detroit River.

Data Processing (updated)

All data entry and QC have been completed.

Mid-season QC Check Findings (from fall report)

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 (from fall report)

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

See U Windsor Fish and Invertebrate section

Other Collaborations

See U Windsor Fish and Invertebrate section

Other Data Requests (from fall report)

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 (from fall report)

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.

EASTERN BASIN FISH, INVERTEBRATE AND WATER QUALITY TEAM, CANADIAN WILDLIFE SERVICE

Team Members

- Joe Fiorino, PI, crew leader, vegetation/WQ/invert sampling (6 years since 2016)
- Ian Smith, team leader, fish/WQ/invert sampling, GIS tech (8 years since 2014)
- Hayley Rogers, team leader, vegetation/WQ/invert sampling (5 years since 2017)
- Lauren Johnson, summer student field tech (2021)
- Tineasha Brenot, summer student field tech (2021)
- Jessica Kassar, summer student field tech (2022)
- Aiden Muir, summer student field tech (2022)

Training (from fall report)

Environment and Climate Change Canada – Canadian Wildlife Service (ECCC-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. A mid field-season check was conducted in mid-August. No problems were identified.

<u>Update</u>

Two new summer students will be joining the ECCC-CWS crew as field technicians in May 2022. Training procedures will be the same as those described above.

Challenges and Lessons Learned

Water Quality Samples (updated)

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 Notre Dame University for analysis). All water quality data have now been received, are entered into the database, and have been quality assured (field and lab, including 2020).

Site Visit List (updated)

No benchmark sites are anticipated for 2022. As in previous years, the number of sites assigned to the ECCC-CWS field crew (20) exceeds crew capacity, so up to 8 sites will likely be traded to another crew (UWindsor or SUNY-Brockport). These arrangements are yet to be determined.

Panel Survey Results

Fall report only. Nothing to add.

Extra Sites and Data

Fall report only. Nothing to add.

Wetland Condition Observations and Results

Fall report only. Nothing to add.

Data Processing (updated)

All fish and field-collected water quality data have been entered into the database and quality assured. Laboratory water quality results from the National Laboratory for Environmental Testing (NLET) were received in December 2021, and have been entered into the database and quality assured. All of the macroinvertebrate samples have been examined, identified to the family level, entered into the database, and the identifications quality checked according to QAPP protocols (by UWindsor). All chlorophyll-a samples (analyzed by University of Notre Dame) were received, entered into the database, and quality assured.

Mid-season QC Check Findings

Fall report only.

Audit and QC Report and Findings (updated)

All data have been QC'ed by an experienced crew member with multiple years of experience working with the data entry system. All additional QC concerns identified by Todd Redder and Valerie Brady (e.g., GPS waypoint mismatches, checks on water quality data) have been addressed.

Additional Funding and Projects (updated)

In 2021-22, ECCC-CWS received funding from the International Joint Commission (IJC) to update marsh bird ecological performance indicators used for adaptive management of outflow regulation on Lake Ontario. ECCC-CWS received support from the bird/anuran team in December 2021 to conduct an analysis using CWMP bird data, and ultimately identified six potential bird-based indicators for consideration by the IJC.

Project description:

The Great Lakes – St. Lawrence River Adaptive Management (GLAM) Committee is continuing in the implementation of its long-term strategy to ensure a full review of the Lake Superior and Lake Ontario outflow regulation plans in the 15 year review period specified in the updated Orders of Approval. On Lake Ontario specifically, the GLAM Committee has been directed and funded to undertake an expedited review of Plan 2014 over the coming three years. As part of that process, the committee is reviewing the existing ecosystem performance indicators (hereafter, PIs) within the Lake Ontario – St. Lawrence River system to assess which PIs can and should be tracked long-term to provide useful information supporting evaluation of Lake

Ontario outflow regulation strategies. Since its creation, the GLAM Committee has put considerable resources into the wetland vegetation PI for Lake Ontario, as it was a critical indicator used in the decision to move forward with Plan 2014, the current regulation plan. While this is expected to continue, other ecosystem PIs may need to be monitored, assessed and considered for the potential to simulate outcomes. The purpose of the 2021-22 project was to consider using existing long-term datasets to update and validate marsh bird PIs for Lake Ontario, and provide a framework for updating PIs for other priority taxa.

Other Collaboration Activities

Nothing to add since fall report.

Other Data Requests (updated)

In February 2022, ECCC-CWS received a request from Gerry McKenna (Ontario Power Generation) for a summary of water quality, fish, turtle, macroinvertebrate, vegetation, bird, and anuran data collected from Wesleyville Marsh (5217) for all sample years (2011, 2012, 2016, 2021). This request was fulfilled.

In March 2022, ECCC-CWS received a request from Jacob Ziegler (Senior Auditor, Office of the Auditor General of Ontario) for all nonnative species data from all Ontario sites for all sample years (2011-2021). These data were to be used to determine whether there were non-native species occurrences in Ontario that provincial government agencies were unaware of. The request was fulfilled.

Related Student Research

None at this time.

EASTERN BASIN VEGETATION TEAM, CANADIAN WILDLIFE SERVICE

Team Members

- Joe Fiorino, PI, crew leader, vegetation/WQ/invert sampling (6 years since 2016)
- Ian Smith, team leader, fish/WQ/invert sampling, GIS tech (8 years since 2014)
- Hayley Rogers, team leader, vegetation/WQ/invert sampling (5 years since 2017)
- Lauren Johnson, summer student field tech (2021)
- Tineasha Brenot, summer student field tech (2021)
- Jessica Kassar, summer student field tech (2022)

- Aiden Muir, summer student field tech (2022)

Training (from fall report)

Environment and Climate Change Canada – Canadian Wildlife Service (ECCC-CWS) field crew members were trained by Joe Fiorino and Hayley Rogers. 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 for GPS use, measuring and spacing of transects, filling out datasheets properly, ensuring species coverages are recorded correctly and standardized, and collecting and taking notes for unknown plant specimens. 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.

Update

Two new summer students will be joining the ECCC-CWS crew in May 2022. Training procedures similar to last year will occur prior to the 2022 field season.

Challenges and Lessons Learned

Nothing to add since fall report.

Site Visit List

No benchmark sites are anticipated for 2022. As in previous years, the number of assigned sites (20) exceeds the capacity of the ECCC-CWS field crew, so up to 8 sites will likely be traded to another crew (UWindsor or SUNY-Brockport). These arrangements are yet to be determined.

Panel Survey Results

Fall report only. Nothing to add.

Extra Sites and Data

Fall report only. Nothing to add.

Wetland Condition Observations and Results

Fall report only. Nothing to add.

Data Processing (Updated)

All vegetation data have been entered and quality assured. Geospatial data for vegetation transects were mapped in GIS to verify that quadrat waypoints were recorded correctly and that transect direction, spacing, and widths were accurate.

Mid-season QC Check Findings

Fall report only.

Audit and QC Report and Findings (updated)

All data have been QC'ed by an experienced crew member with multiple years of experience working with the data entry system. All additional QC concerns identified by Todd Redder and Valerie Brady (e.g., GPS waypoint mismatches, instances where total vegetated cover + unvegetated cover did not equal 100%) have been addressed.

Additional Funding and Projects

See fish, invertebrate, and water quality team report above.

Other Collaboration Activities

Nothing to add since fall report.

Other Data Requests

See fish, invertebrate, and water quality team report above.

Related Student Research

None at this time.

EASTERN BASIN BIRD AND ANURAN TEAM, SUNY BROCKPORT

Team Members

- Dr. Kathryn Amatangelo, PI (8 years since 2014)
- Gregory Lawrence, acting bird and anuran PI, project manager (4 years 2011-14, 4 years since 2018)
- Ray Marszalek, graduate research assistant and bird and anuran team lead (1 year since 2021)
- Robert Buckert, undergraduate research assistant (1 year since 2021)

Training

Both field technicians (R. Marszalek and R. Buckert) were trained by project manager and field crew lead Gregory Lawrence 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.

<u>Update</u>

Both field technicians (R. Marszalek and R. Buckert) will return for the 2022 field season. They both already successfully passed the bird and anuran identification and certification tests in 2021 and will go through routine pre-season training conducted by project manager Gregory Lawrence in Spring 2022 as per performance criteria described in the project QAPP.

Challenges and Lessons Learned (from fall report)

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 reducing standing water near the edges of the wetland, where bird and anuran sampling occur. Some sites required long walks to take water temperature 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 31. Field technician R. Buckert walking out to sampling point.

Site Visit List (updated)

SUNY Brockport Bird and Anurans teams plan on sampling a total of 28 sites across the US Eastern Basin including 19 regular panel sites, 1 panel re-sample site, 3 panel pre-sample sites, and 3 non-panel (benchmark) sites in 2022. Guffin Bay (site 164) is the sole re-sample site, and Little Sandy Creek Marsh (site 123), South Colwell (site 7021), and Buckthorn Island Wetland (site 119) are the three panel pre-sample sites. Cranberry Pond Wetland (site 50) will be sampled again as a non-panel benchmark site to supplement targeted surveys as part of post-restoration monitoring for a NFWF-funded Audubon Great Lakes/Ducks Unlimited restoration project within the Rochester Embayment AOC completed in Spring 2021. Eighteenmile Creek Wetland (Site 5) will be sampled as a non-panel benchmark site as it has only been sampled by the bird and anuran crew in past years and has historically been over capacity for summer crews. This site had the lowest bird and anuran IEC scores of all sites not sampled by the fish, invertebrate, water quality, and vegetation crews in the US Eastern Basin and also lies within the Eighteenmile Creek AOC so sampling will be part of an attempt to monitor sites at extremes along the environmental quality gradient.

Panel Survey Results (from fall report)

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 (from fall report)

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 32. 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 (from fall report)

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 (from fall report)

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 (from fall report)

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 (updated)

Data entry QC work from 2021 sampling sufficiently resolved consistency errors in data recording and all issues are resolved. One significant finding was a small issue in recording GPS points where technicians submitted points too fast on the GPS without allowing the unit to find satellites and update the observers' location. This only happened a few times but is a systematic error we've resolved and will highlight during future GPS training sessions.

Second, QC audits on GPS points from the past 11 years of sampling highlighted issues with point naming consistency. We have now updated all master point locations with correct point names and locations for crews to use in subsequent sampling years. We also noted some species recorded in past years, which are likely misidentified birds not present in those habitats and regions. The only major issue here was with Swainson's and Hermit Thrushes, which are native to higher elevation forests and not coastal wetlands or lowland forests. Newer crews will have extra training in the future to ensure technicians know how to identify the more expected Wood Thrush and Veery from the less expected Swainson's and Hermit Thrush.

Additional Funding and Projects

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

Other Collaboration Activities (updated)

Bird and anuran data and sampling at benchmark sites continue to supplement post-restoration monitoring activities. Data were used to supplement the NFWF and Audubon-funded wetland restoration project at Cranberry Pond (50) and ACOE and USEPA-funded restoration project at Braddock Bay (7052) within the Rochester Embayment AOC.

Figure 33. Common Yellowthroat (*Geothlypis trichas*) at site 133, Stony Creek.

Other Data Requests (updated)

Bird and anuran data were shared with partners at New York State Office of Parks and Historic Preservation to help the agency guide restoration projects in coastal wetlands in this region, including Yanty Marsh (15), where a USEPA-funded restoration project is scheduled to be implemented in 2023. These data were also shared with partners at the New York State Department of Environmental Conservation for the following eight sites: East Bay Wetland (66), Beaver Creek Wetland (69), Port Bay Wetland (70), Deaborough Park Wetland (72), Red Creek Wetland (76), Black Creek Wetland (79), Blind Sodus Bay Wetland (82), and Sterling Creek Wetland (86). They will use these data to support the Sterling-Wolcott Integrated Watershed Action Plan (IWAP) pilot project to evaluate appropriate indicators of coastal wetland condition, risks of coastal wetlands, and assist in development of strategies within the Sterling-Wolcott Creek watersheds.

EASTERN BASIN FISH, INVERTEBRATE, AND WATER QUALITY TEAM, SUNY BROCKPORT

Team Members

- Dr. Kathryn Amatangelo, PI (8 years since 2014)
- Dr. Matthew Altenritter, PI (2 years since 2020)
- Dr. Michael Chislock, PI (4 years since 2018)

- Gregory Lawrence, project manager (4 years 2011-14, 4 years since 2018)
- Madelynn Edwards, invertebrate laboratory technician (3 years since 2019)
- 2 new graduate research assistants starting summer 2022
- 2 new undergraduate research assistants starting summer 2022

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.

<u>Update</u>

Two new graduate research assistants and two new undergraduate research assistants will be conducting fish, aquatic macroinvertebrate, and water quality monitoring for the 2022 field season and will be trained by PIs Dr. Kathryn Amatangelo, Dr. Michael Chislock, Dr. Matthew Altenritter, and project manager Gregory Lawrence as per 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.

<u>Update</u>

Crews will continue to improve GPS point matching, which was very high this past year by ensuring points are recorded accurately by hand on the data sheets and in the correct units and format.

Site Visit List (updated)

The SUNY Brockport fish, invertebrate, and water quality team plans on sampling a total of 16 sites across the US Eastern Basin including 9 regular panel sites, 1 panel re-sample site, 3 panel pre-sample sites, and 3 non-panel (benchmark) sites in 2022. Guffin Bay (site 164) is the sole re-sample site, and Little Sandy Creek Marsh (site 123), South Colwell (site 7021), and Buckthorn Island Wetland (site 119) are the three panel pre-sample sites. Cranberry Pond Wetland (site 50) will be sampled again as a non-panel benchmark site to supplement targeted surveys as part of post-restoration monitoring for a NFWF-funded Audubon Great Lakes/Ducks Unlimited restoration project within the Rochester Embayment AOC completed in Spring 2021. Eighteenmile Creek Wetland (site 5) will be sampled as a non-panel benchmark site as it has only been sampled by the bird and anuran crew in past years and has historically been over capacity for summer crews. This site had the lowest bird and anuran IEC scores of all sites not sampled by the fish, invertebrate, water quality, and vegetation crews in the US Eastern Basin and also lies within the Eighteenmile Creek AOC so sampling will be part of an attempt to monitor sites at extremes along the environmental quality gradient.

Panel Survey Results (from fall report)

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.

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 (from fall report)

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.

Update

Crews finished winter laboratory invertebrate and water quality processing. These data were shared with project partners to supplement post-restoration monitoring. Data supplemented USEPA-funded NYSDEC monitoring for the Braddock Bay restoration project and the NFWF-funded Audubon restoration project at Cranberry Pond, both within the Rochester Embayment AOC. Further, water quality and invertebrate data helped fill in a major gap in our dataset at Stony Creek (site 133), which had only been sampled for birds and anurans in the past as it was above crew capacities for the fish, invertebrate, and water quality crews. This site had high invertebrate species richness including a few rarely found in coastal wetlands, Elmidae.

Wetland Condition Observations and Results (from fall report)

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 (updated)

100% laboratory water quality analyses, data entry, and QC checks were completed. Further, 100% laboratory invertebrate processing and identification was completed and 100% data entry, QC checks were completed. Lastly, the annual invertebrate sample QC swap with University of Windsor PIs and technicians per requirements in the project QAPP.

Mid-season QC Check Findings (from fall report)

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 (updated)

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. 100% data entry and QC checks were completed for invertebrate laboratory samples. We completed the invertebrate sample QC swap with University of Windsor PIs and technicians per requirements in the project QAPP. Our technicians report was largely positive and consistent with the findings of the University of Windsor team.

Additional Funding and Projects

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

Other Collaboration Activities (from fall report)

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.

<u>Update</u>

SUNY Brockport invertebrate technicians are collaborating with other invertebrate crews and teams from across the basin to further investigate factors influencing the presence, intensity, and prevalence of parasitic mites on Hemiptera and Odonata in Great Lakes Coastal Wetlands. Collaborative efforts can elucidate trends across the basin and across years and also determine if mites are indicators of site quality.

Other Data Requests (updated)

Fish, invertebrate, and water quality data were shared with partners at New York State Office of Parks and Historic Preservation to help the agency guide restoration projects in coastal wetlands in this region, including Yanty Marsh (15), where a USEPA-funded restoration project is scheduled to be implemented in 2023. These data were also shared with partners at the New York State Department of Environmental Conservation for the following six sites: East Bay Wetland (66), Port Bay Wetland (70), Red Creek Wetland (76), Black Creek Wetland (79), Blind Sodus Bay Wetland (82), and Sterling Creek Wetland (86). They will use these data to support the Sterling-Wolcott Integrated Watershed Action Plan (IWAP) pilot project to evaluate appropriate indicators of coastal wetland condition, risks of coastal wetlands, and assist in development of strategies within the Sterling-Wolcott Creek watersheds.

EASTERN BASIN VEGETATION TEAM, SUNY BROCKPORT

Team Members

- Dr. Kathryn Amatangelo, PI (8 years since 2014)
- Dr. Rachel Schultz, PI (3 years since 2019)
- Gregory Lawrence, project manager (4 years 2011-14, 4 years since 2018)
- Kevin Killigrew, graduate research assistant and 2022 field crew leader (3 years since 2019)
- Braeden Schmidt, undergraduate research assistant (new Summer 2022)

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.

<u>Update</u>

Kevin Killigrew and Braeden Schmidt will be conducting plant surveys for the 2022 field season and will be trained by PIs Dr. Rachel Schultz, Dr. Kathryn Amatangelo and project manager Gregory Lawrence as per 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.

<u>Update</u>

Crews will continue to improve GPS point matching, which was very high this past year by ensuring points are recorded accurately by hand on the data sheets and in the correct units and format.

Site Visit List (updated)

The SUNY Brockport Vegetation team plans on sampling a total of 16 sites across the US Eastern Basin including 9 regular panel sites, 1 panel re-sample site, 3 panel pre-sample sites, and 3 non-panel (benchmark) sites in 2022. Guffin Bay (site 164) is the sole re-sample site, and Little Sandy Creek Marsh (site 123), South Colwell (site 7021), and Buckthorn Island Wetland (site 119) are the three panel pre-sample sites. Cranberry Pond Wetland (site 50) will be sampled again as a non-panel benchmark site to supplement targeted surveys as part of post-restoration monitoring for a NFWF-funded Audubon Great Lakes/Ducks Unlimited restoration project within the Rochester Embayment AOC completed in Spring 2021. Eighteenmile Creek Wetland (site 5) will be sampled as a non-panel benchmark site as it has only been sampled by the bird and anuran crew in past years and has historically been over capacity for summer crews. This site had the lowest bird and anuran IEC scores of all sites not sampled by the fish, invertebrate, water quality, and vegetation crews in the US Eastern Basin and also lies within the Eighteenmile Creek AOC so sampling will be part of an attempt to monitor sites at extremes along the environmental quality gradient.

Panel Survey Results (from fall report)

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. 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 35).

Extra Sites and Data (from fall report)

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 34. 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 (from fall report)

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 (from fall report)

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 (from fall report)

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.

Update

Plant crew PI Dr. Rachel Schultz conducted a data audit and found no issues with plant IDs from 2021 data collection and sampling. If ID issues are found, targeted training sessions and workshops in the lab and in the field would be used to better train crew members on difficult identifications.

Additional Funding and Projects

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

Other Collaboration Activities (from fall report)

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.

Other Data Requests (updated)

Vegetation data were shared with partners at New York State Office of Parks and Historic Preservation to help the agency guide restoration projects in coastal wetlands in this region, including Yanty Marsh (Site 15), where a USEPA-funded restoration project is scheduled to be implemented in 2023. These data were also shared with partners at the New York State

Department of Environmental Conservation for the following six sites: East Bay Wetland (66), Port Bay Wetland (70), Red Creek Wetland (76), Black Creek Wetland (79), Blind Sodus Bay Wetland (82), and Sterling Creek Wetland (86). They will use these data to support the Sterling-Wolcott Integrated Watershed Action Plan (IWAP) pilot project to evaluate appropriate indicators of coastal wetland condition, risks of coastal wetlands, and assist in development of strategies within the Sterling-Wolcott Creek watersheds.

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 USEPA reviewed and signed the updated document prior to commencing fieldwork. The final QAPP revision for round 1 of the project was signed in March 2015. This 2015 revision (QAPP_r5) served as the basis for the second round of monitoring (2016-2020).

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

For the third 5-year sampling rotation (2021-2025), 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 work:

- Training of all new laboratory staff responsible for macroinvertebrate sample processing: This training is conducted by experienced technicians at each regional lab and is overseen by the respective co-PI or resident macroinvertebrate expert. Those labs without such an expert send their new staff to the closest collaborating lab for training. Macroinvertebrate IDers communicate with each other via their own email list and assist each other with difficult identifications and other questions that arise. Every few years, typically when a major identification guide is updated, IDers for all teams meet either in-person or virtually to discuss taxonomic issues and questions.

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

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

- Review of sites rejected after initial site visits: In cases where a site was rejected during a site visit, the reason for rejection was documented by the field crew in the site selection database. The project QA managers (Brady and Cooper) then reviewed these records to ensure consistency among crews. Occasionally, field crew leaders contacted Uzarski, Brady, or Cooper 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 are calibrated and maintained according to manufacturer recommendations. Calibration/maintenance records are being archived at each institution.

- Collection of duplicate field samples: Precision and accuracy of many field-collected variables is being evaluated with duplicate samples. Duplicate water quality samples are collected at approximately every 10th 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 are completed by PIs or head field crew leaders for each of the field crews to ensure that there are no sampling issues that develop after training and while crews are sampling on their own.

- Creation/maintenance of specimen reference collections: Reference collections for macroinvertebrates, fish, and plants have either been created or are being maintained and updated by each regional team. Macroinvertebrate reference collections, in particular, were developed or expanded as these samples were processed. 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 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 CWMP database release (MS Access format) that is 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 36). 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.

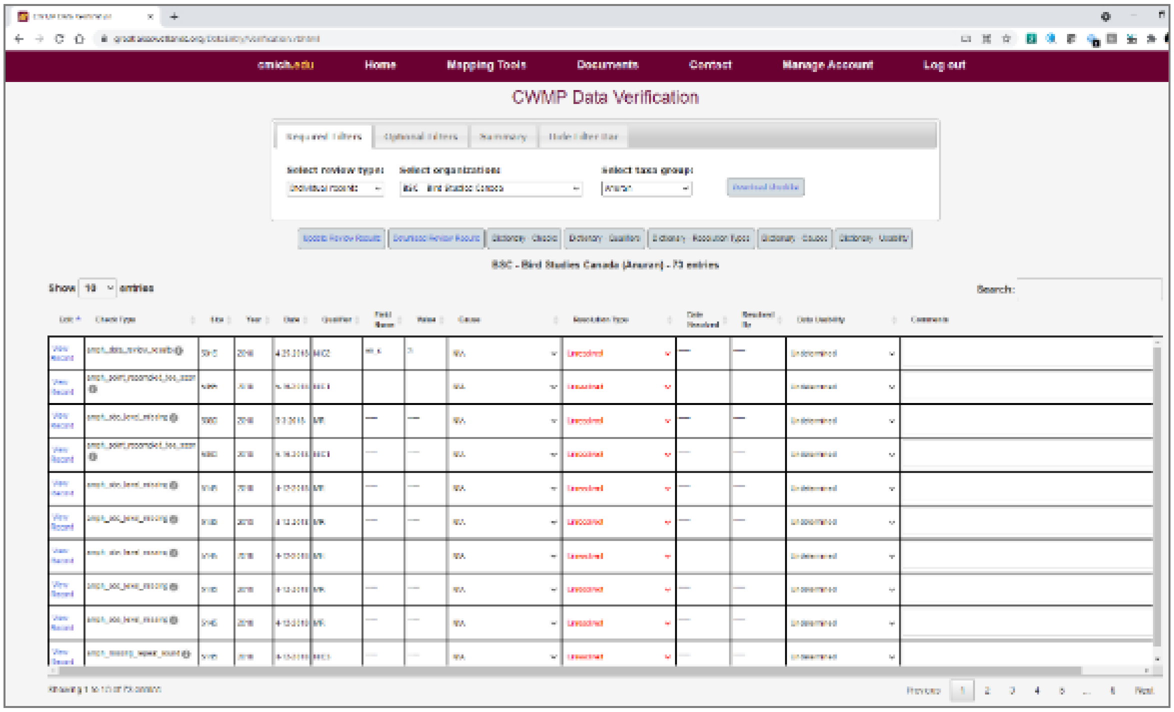

Figure 35. CWMP data verification user interface.

The CWMP lead PIs have finished reviewing most of the verification criteria information provided by GLNPO and GDIT, as well as the data verification tool described above. 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, probably in fall of 2022.

EXAMPLE WATER QUALITY QC INFORMATION

Laboratory Quality Assurances

Water quality analyses from 2021 have been completed by the NRRI Central Analytical Laboratory, Central Michigan University's Wetland Ecology Laboratory, Grand Valley State University's Annis Water Resources Institute, Brockport's water quality lab, and Environment Canada's national water quality lab. Laboratory results from 2021 have passed the criteria shown below (Table 17) or were excluded from the database.

Table 17. Data acceptance criteria for water quality analyses.

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

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

Variability in Field Replicates

An analysis of field duplicate variability for samples collected in 2020 and 2021 is shown in Table 18. It is important to note that for many constituents, the variability within sample sets is related to the mean concentration, and as concentrations approach the method detection limit (MDL), the variability increases dramatically. A calculation of field replicate variability with values at or near the level of detection will often result in high RPDs. For example, if the chlorophyll measurements on a set of field duplicates are 0.8 µg/L and 0.3 µg/L, mean = 0.6, resulting in a RPD of 91% (RPD = [abs (rep a-rep b)/ (rep a+ rep b)/2)]*100, but since the MDL is ± 0.5 µg/L, this can be misleading.

The same can occur with analyte lab duplicates, and in these instances the QA officer or personnel at the respective analytical lab will determine whether data are acceptable. It is also important to note that RPD on field duplicates incorporates environmental (e.g., spatial) variability, since duplicate samples are collected from adjacent locations, as well as analytical variability (e.g., instrument drift). Therefore, RPD of field duplicates is generally higher than RPD of laboratory duplicates. Table 18 below lists average RPD values for the past two sampling seasons. 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 18. Field duplicate sample variability for 2020-2021 in relative percent difference for water quality parameters with the acceptance criteria. The maximum expected RPD values are based on the MN Pollution Control Agency quality monitoring requirements for integrated assessments (https://www.pca.state.mn.us/sites/default/files/wq-s1-15n.pdf). Average RPD (n), min-max RPD.

Analyte	Maximum expected RPD	MDL	2020	2021
Chlorophyll-a (µ/L)	30	0.5 µg/l All Labs 0.025 µg/L Brockport 0.25 µg/L U Windsor	22 (15) 0-113	31 (18) 0-133
Total phosphorus (mg/L)	30	0.002 mg/L Brockport 0.01 mg/L CMU 0.0005 mg/L Env Can 0.006 mg/L GVSU 0.005 mg/L NRRI 0.0005 mg/L U Windsor	15 (15) 0-37	17 (18) 0-97
*Soluble Reactive phosphorus (mg/L)	10	0.0003 mg/L Brockport 0.006 mg/L CMU 0.0002 mg/L Env Can 0.005 mg/L GVSU 0.006 mg/L NRRI 0.0002 mg/L U Windsor	34 (12) 0-119	38 (16) 0-150
Total nitrogen (mg/L)	30	0.023 mg/L Brockport 0.03 mg/L CMU 0.015 mg/L Env Can 0.1 mg/L GVSU 0.03 mg/L NRRI 0.015 mg/L U Windsor	9 (15) 0-23	9 (18) 0-48
*NH4-N (mg/L)	10	0.002 mg/L Brockport 0.01 mg/L CMU 0.005 mg/L Env Can 0.01 mg/L GVSU 0.009 mg/L NRRI 0.005 mg/L U Windsor	18 (14) 0-93	17 (16) 0-42
*NO2/NO3-N (mg/L)	10	0.003 mg/L Brockport 0.01 mg/L CMU 0.005 mg/L Env Can 0.01 mg/L GVSU	10 (13) 0-33	16 (18) 0-57

Analyte	Maximum expected RPD	MDL	2020	2021
		0.008 mg/L NRRI 0.005 mg/L U Windsor		
True color (Pt-Co Units)	10	2 CU Brockport 5 CU Env Can 2 CU NRRI 0.5 CU U Windsor	5 (12) 0-12	14 (12) 0-44
Chloride (mg/L)	20	0.2 mg/L CMU 0.1 mg/L Env Can 1 mg/L GVSU 1.67 mg/L NRRI 0.01 mg/L U Windsor	8 (14) 0-43	7 (16) 0-42

Notes:
*The variability between soluble reactive phosphorus, ammonium-N and nitrate/nitrite-N field replicates often exceeded the criteria, however many values for each were < 10 X the MDL

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 4, 2022. 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 any remaining Covid 19 issues and border closures, manuscript topics, and report products. Individual taxonomic teams held their meetings virtually just before or after 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 because of Covid-19 (depending on the field crew and PI), but we expect that this field season will be more normal. However, again this year most crews have returning and experienced personal, and the PIs will be in contact and do training and provide advice in the manner that best suits their circumstances, at a minimum via phone calls and webinars. Under all circumstances, PIs keep in close contact with crews via cell phone, text, and email, and the leadership team is also always available via cell phone and text to answer crew questions.

OVERALL

The quality management system developed for this program has been fully implemented and PIs and their respective staff members continue to follow established protocols very closely, relying on the QAPP and SOPs as guiding documents. QA managers are also encouraged by each crew's continued willingness to contact their supervisors or, in many cases, the project management team when questions arise.

Despite the somewhat dangerous nature of this work, injury rates continue to be very low. We are very proud of what our field crews accomplished safely 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 – 2022)

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.

Macroinvertebrate Monitoring for Delisting the Degradation of Benthos Beneficial Use Impairment in the Muskegon Lake Area of Concern: The West Michigan Shoreline Regional Development Commission, with support from the Michigan Department of Environment, Great Lakes, and Energy funded a project to conduct macroinvertebrate sampling at 2 coastal wetlands in the Muskegon Lake Area of Concern in an effort to evaluate "Degradation of Benthos" BUI in the AOC. Samples were collected in 2021 and data from several Lake Michigan reference wetlands were used to compare the AOC restoration sites. Dr. Matt Cooper led this project with students from Muskegon Community College who assisted with fieldwork.

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

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

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

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

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

STUDENT RESEARCH SUPPORT

<u>Graduate Research with Leveraged Funding:</u>

- 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)

<u>Undergraduate Research with Leveraged Funding:</u>

- Production of a short documentary film on Great Lakes coastal wetlands (University of Notre Dame; additional funding by the UND College of Arts and Letters).
- Heavy metal loads in freshwater turtle species inhabiting coastal wetlands of Lake Michigan (University of Notre Dame; additional funding by the UND College of Science, and ECI – Environmental Change Institute). Online coverage, TV and radio.
- Nitrogen-limitation in Lake Superior coastal wetlands (Northland College; additional funding from the Wisconsin DNR and Northland College).
- Patterns in chlorophyll-*a* concentrations in Great Lakes coastal wetlands (Northland College; additional funding provided by the college).
- *Phragmites australis* effects on coastal wetland nearshore fish communities of the Great Lakes basin (University of Windsor; with additional funding from GLRI GLIC: GLEI II).
- Sonar-derived estimates of macrophyte density and biomass in Great Lakes coastal wetlands (University of Windsor; with additional funding from GLRI GLIC: GLEI II presented at the International Association for Great Lakes Research annual meeting).
- Effects of disturbance frequency on the structure of coastal wetland macroinvertebrate communities (Lake Superior State University; with additional funding from LSSU's Undergraduate Research Committee; awarded Best Student Poster award at LSSU Research Symposium; presented at MI American Fisheries Society annual meeting).
- Resistance and resilience of macroinvertebrate communities in disturbed and undisturbed coastal wetlands (Lake Superior State University; with additional funding from LSSU's Undergraduate Research Committee, (presented at MI American Fisheries Society annual meeting and Midwest Fish and Wildlife Conference).
- Structure and function of restored Roxana Marsh in southern Lake Michigan (University of Notre Dame, with additional funding from the UND College of Science)

- Nutrient limitation in Great Lakes coastal wetlands (Central Michigan University, CMU Biological Station on Beaver Island)
- Effects of wetland size and adjacent land use on taxonomic richness (University of Minnesota Duluth, with additional funding from UMD's UROP program)
- Water depth optima and tolerances for St. Louis River estuary wetland plants (University of Wisconsin-Superior, with additional funding from WI Sea Grant)
- Mapping Wetland Areal Change in the St. Louis River Estuary Using GIS (University of Wisconsin-Superior, with additional funding from WI Sea Grant)
- An analysis of Microcystin concentrations in Great Lakes coastal wetlands (Central Michigan University; additional funding by CMU College of Science and Engineering).
- Bathymetry and water levels in lagoonal wetlands of the Apostle Islands National Lakeshore (Northland College; additional funding from the National Park Service). Several presentations at regional meetings and IAGLR.
- Non-native fish use of Great Lakes coastal wetlands (Northland College funding). Poster presentations by Northland College students at Wisconsin Wetland Science Meeting and IAGLR.

Graduate Research without Leveraged Funding:

- Impacts of drainage outlets on Great Lakes coastal wetlands (Central Michigan University).
- Effects of anthropogenic disturbance affecting coastal wetland vegetation (Central Michigan University).
- Great Lakes coastal wetland seed banks: what drives compositional change? (Central Michigan University).
- Spatial scale variation in patterns and mechanisms driving fish diversity in Great Lakes coastal wetlands (Central Michigan University).
- Building a model of macroinvertebrate functional feeding group community through zone succession: Does the River Continuum Concept apply to Great Lakes coastal wetlands? (Central Michigan University).
- Chemical and physical habitat variation within Great Lakes coastal wetlands; the importance of hydrology and dominant plant zonation (Central Michigan University)
- Macroinvertebrate-based Index of Biotic Integrity for Great Lakes coastal wetlands (Central Michigan University)
- Habitat conditions and invertebrate communities of Great Lakes coastal habitats dominated by Wet Meadow, and *Phragmites australis*: implications of macrophyte structure changes (Central Michigan University)

- The establishment of *Bithynia tentaculata* in coastal wetlands of the Great Lakes (Central Michigan University)
- Environmental covariates as predictors of anuran distribution in Great Lakes coastal wetlands (Central Michigan University)
- Impacts of muskrat herbivory in Great Lakes coastal wetlands (Central Michigan University).
- Mute swan interactions with native waterfowl in Great Lakes coastal wetlands (Central Michigan University).
- Effects of turbidity regimes on fish and macroinvertebrate community structure in coastal wetlands (Lake Superior State University and Oakland University).
- Scale dependence of dispersal limitation and environmental species sorting in Great Lakes wetland invertebrate meta-communities (University of Notre Dame).
- Spatial and temporal trends in invertebrate communities of Great Lakes coastal wetlands, with emphasis on Saginaw Bay of Lake Huron (University of Notre Dame).
- Model building and a comparison of the factors influencing sedge and marsh wren populations in Great Lakes coastal wetlands (University of Minnesota Duluth).
- The effect of urbanization on the stopover ecology of Neotropical migrant songbirds on the western shore of Lake Michigan (University of Minnesota Duluth).
- Assessing the role of nutrients and watershed features in cattail invasion (*Typha angustifolia* and *Typha* x *glauca*) in Lake Ontario wetlands (The College at Brockport).
- Developing captive breeding methods for bowfin (*Amia calva*) (The College at Brockport).
- Water chestnut (*Trap natans*) growth and management in Lake Ontario coastal wetlands (The College at Brockport).
- Functional diversity and temporal variation of migratory land bird assemblages in lower Green Bay (University of Wisconsin-Green Bay).
- Effects of invasive *Phragmites* on stopover habitat for migratory shorebirds in lower Green Bay, Lake Michigan (University of Wisconsin-Green Bay).
- Plant species associations and assemblages for the whole Great Lakes, developed through unconstrained ordination analyses (Oregon State University).
- Genetic barcoding to identify black and brown bullheads (Grand Valley State University).
- Coastal wetland – nearshore linkages in Lake Michigan for sustaining sport fishes (University of Notre Dame)
- Anthropogenic disturbance effects on bird and anuran communities in Lake Ontario coastal wetlands (The College at Brockport)
- A fish-based index of biotic integrity for Lake Ontario coastal wetlands (The College at Brockport)

- Modeling potential nutria habitat in Great Lakes coastal wetlands (Central Michigan University)
- Modeling of Eurasian ruffe (*Gymnocephalus cernua*) habitat preferences to predict future invasions (University of Minnesota Duluth in collaboration with USEPA MED)
- Modeling species-specific habitat associations of Great Lakes coastal wetland birds (University of Minnesota)
- The effect of urbanization on the stopover ecology of Neotropical migrant songbirds on the western shore of Lake Michigan (University of Minnesota Duluth).
- Nutrient limitation in Great Lakes coastal wetlands: gradients and their influence (Central Michigan University; with additional funding from the CMU College of Science and Engineering)
- Invasive *Phragmites australis* management (Central Michigan University; with additional funding from the CMU College of Science and Technology)
- The relationship between vegetation and ice formation in Great Lakes coastal wetlands (Central Michigan University; with additional funding from CMU College of Science and Engineering)
- PFAS accumulation by Dressenidae *spp* in Great Lakes Coastal Wetlands (Central Michigan University)
- Development of a vegetation based IBI for Great Lakes Coastal Wetlands (Central Michigan University)
- Development of a model for Great-Lakes wide invasive plant harvest for bioenergy production and nutrient recycling (Loyola Chicago and Oregon State University)
- Updating the Macroinvertebrate-based Index of Biotic Integrity for Great Lakes coastal wetlands (Central Michigan University)

Undergraduate Research without Leveraged Funding:

- Sensitivity of fish community metrics to net set locations: a comparison between Coastal Wetland Monitoring and GLEI methods (University of Minnesota Duluth).
- Larval fish usage and assemblage composition between different wetland types (Central Michigan University).
- Determining wetland health for selected Great Lakes Coastal Wetlands and incorporating management recommendations (Central Michigan University).
- Invertebrate co-occurrence trends in the wetlands of the Upper Peninsula and Western Michigan and the role of habitat disturbance levels (Central Michigan University).

- Is macroinvertebrate richness and community composition determined by habitat complexity or variation in complexity? (University of Windsor, complete; Published in *Ecosphere*).
- Modeling American coot habitat relative to faucet snail invasion potential (Central Michigan University).
- Nutrient uptake by *Phragmites australis* and native wetland plants (Central Michigan University).
- Comparison of the diagnostic accuracy two aquatic invertebrate field collection and laboratory sorting methods (University of Windsor, complete).
- Validation of a zoobenthic assemblage condition index for Great Lakes coastal wetlands (University of Windsor, complete).
- Water depth-related variation in net ecosystem production in a Great Lakes coastal wet meadow (University of Windsor, complete).
- Anuran habitat use in the Lower Green Bay and Fox River Area of Concern (University of Wisconsin-Green Bay with support from GLRI/AOC funding).
- Impacts of European frog-bit invasion on wetland macroinvertebrate communities (Lake Superior State University; presented at Midwest Fish and Wildlife Conference).
- Effects of European frog-bit on water quality and fish assemblages in St. Marys River coastal wetlands (Lake Superior State University; presented at Midwest Fish and Wildlife Conference).
- Functional diversity of macroinvertebrates in coastal wetlands along the St. Marys River (Lake Superior State University; awarded Best Student Poster award at LSSU Research Symposium; presented at Midwest Fish and Wildlife Conference).
- A comparison of macroinvertebrate assemblages in coastal wetlands exposed to varying wave disturbance (Lake Superior State University; presented at MI American Fisheries Society annual meeting).
- Coastal wetlands as nursery habitat for young-of-year fishes in the St. Marys River (Lake Superior State University; presented at MI American Fisheries Society annual meeting)
- Relationship between water level and fish assemblage structure in St. Marys River coastal wetlands (Lake Superior State University; presented at MI American Fisheries Society annual meeting)
- Dominance patterns in macroinvertebrate communities in Great Lakes coastal wetlands: does environmental stress lead to uneven community structure? Northland College.
- Understanding drivers of chlorophyll-a in Great Lakes coastal wetlands. University of Notre Dame

Jobs Created/Retained (2020):

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

Total jobs at least partially supported in 2020: 105.
Students and post-doctoral researchers trained in 2020: 44.

Jobs Created/Retained (cumulative since 2011):

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

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

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

PRESENTATIONS ABOUT THE COASTAL WETLAND MONITORING PROJECT
(INCEPTION THROUGH 2019)

Albert, Dennis. 2013. Use of Great Lakes Coastal Wetland Monitoring data in restoration projects in the Great Lakes region. 5th Annual Conference on Ecosystem Restoration, Schaumburg, IL. July 30, 2013. 20 attendees, mostly managers and agency personnel.

Albert, Dennis. 2013. Data collection and use of Great Lakes Coastal Wetland Monitoring data by Great Lakes restorationists. Midwestern State Wetland Managers Meeting, Kellogg Biological Station, Gull Lake, MI, October 31, 2013. 40 attendees; Great Lakes state wetland managers.

Albert, Dennis, N. Danz, D. Wilcox, and J. Gathman. 2014. Evaluating Temporal Variability of Floristic Quality Indices in Laurentian Great Lakes Coastal Wetlands. Society of Wetland Scientists, Portland, OR. June.

Albert, Dennis, et al. 2015. Restoration of wetlands through the harvest of invasive plants, including hybrid cattail and *Phragmites australis*. Presented to Midwestern and Canadian biologists. June.

Albert, Dennis, et al. 2015. Great-Lakes wide distribution of bulrushes and invasive species. Coastal and Estuarine Research Federation Conference in Portland, Oregon. November.

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

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

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

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

Bozimowski, S. and D.G. Uzarski**.** 2016. The Great Lakes coastal wetland monitoring program. 2016 Wetlands Science Summit, Richfield, OH. September, Oral Presentation.

Bozimowski, A.A., B.A. Murry, and D.G. Uzarski. 2012 Invertebrate co-occurrence patterns in the wetlands of northern and eastern Lake Michigan: the interaction of the harsh-benign hypothesis and community assembly rules. 55th International Conference on Great Lakes Research, Cornwall, Ontario.

Bozimowski, A. A., B. A. Murry, P. S. Kourtev, and D. G. Uzarski. 2014. Aquatic macroinvertebrate co-occurrence patterns in the coastal wetlands of the Great Lakes: the interaction of the harsh-benign hypothesis and community assembly rules. Great Lakes Science in Action Symposium, Central Michigan University, Mt. Pleasant, MI. April.

Bozimowski, A.A., B.A. Murry, P.S. Kourtev, and D.G. Uzarski. 2015. Aquatic macroinvertebrate co-occurrence patterns in the coastal wetlands of the Great Lakes. 58th International Conference on Great Lakes Research, Burlington, VT.

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

Bracey, A. M., R. W. Howe, N.G. Walton, E. E. G. Giese, and G. J. Niemi. Avian responses to landscape stressors in Great Lakes coastal wetlands. 5th International Partners in Flight Conference and Conservation Workshop. Snowbird, UT, August 25-28, 2013.

Brady, V., D. Uzarski, and M. Cooper. 2013. Great Lakes Coastal Wetland Monitoring: Assessment of High-variability Ecosystems. USEPA Mid-Continent Ecology Division Seminar Series, May 2013. 50 attendees, mostly scientists (INVITED).

Brady, V., G. Host, T. Brown, L. Johnson, G. Niemi. 2013. Ecological Restoration Efforts in the St. Louis River Estuary: Application of Great Lakes Monitoring Data. 5th Annual Conference on Ecosystem Restoration, Schaumburg, IL. July 30, 2013. 20 attendees, mostly managers and agency personnel.

Brady, V. and D. Uzarski. 2013. Great Lakes Coastal Wetland Fish and Invertebrate Condition. Midwestern State Wetland Managers Meeting, Kellogg Biological Station, Gull Lake, MI, October 31, 2013. 40 attendees; Great Lakes state wetland managers.

Brady, V., D. Uzarski, T. Brown, G. Niemi, M. Cooper, R. Howe, N. Danz, D. Wilcox, D. Albert, D. Tozer, G. Grabas, C. Ruetz, L. Johnson, J. Ciborowski, J. Haynes, G. Neuderfer, T. Gehring, J. Gathman, A. Moerke, G. Lamberti, C. Normant. 2013. A Biotic Monitoring Program for Great Lakes Coastal Wetlands. Society of Wetland Scientists annual meeting, Duluth, MN, June 2013. 25 attendees, mostly scientists, some agency personnel.

Brady, V., D. Uzarski, T. Brown, G. Niemi, M. Cooper, R. Howe, N. Danz, D. Wilcox, D. Albert, D. Tozer, G. Grabas, C. Ruetz, L. Johnson, J. Ciborowski, J. Haynes, G. Neuderfer, T. Gehring, J.

Gathman, A. Moerke, G. Lamberti, C. Normant. 2013. Habitat Values Provided by Great Lakes Coastal Wetlands: based on the Great Lakes Coastal Wetland Monitoring Project. Society of Wetland Scientists annual meeting, Duluth, MN, June 2013. 20 attendees, mostly scientists.

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

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

Buckley, J.D., and J.J.H. Ciborowski. 2013. A comparison of fish indices of biological condition at Great Lakes coastal margins. 66th Canadian Conference for Freshwater Fisheries Research, Windsor, ON, January 3-5 2013. Poster Presentation.

Chorak, G.M., C.R. Ruetz III, R.A. Thum, J. Wesolek, and J. Dumke. 2015. Identification of brown and black bullheads: evaluating DNA barcoding. Poster presentation at the Annual Meeting of the Michigan Chapter of the American Fisheries Society, Bay City, Michigan. January 20-21.

Cooper, M.J. Great Lakes coastal wetland monitoring: chemical and physical parameters as co-variates and indicators of wetland health. Biennial State of the Lakes Ecosystem Conference, Erie, PA, October 26-27, 2011. Oral presentation.

Cooper, M.J. Coastal wetland monitoring: methodology and quality control. Great Lakes Coastal Wetland Monitoring Workshop, Traverse City, MI, August 30, 2011. Oral presentation.

Cooper, M.J., D.G. Uzarski, and G.L. Lamberti. GLRI: coastal wetland monitoring. Michigan Wetlands Association Annual Conference, Traverse City, MI, August 30-September 2, 2011. Oral presentation.

Cooper, M.J. Monitoring the status and trends of Great Lakes coastal wetland health: a basin-wide effort. Annual Great Lakes Conference, Institute of Water Research, Michigan State University, East Lansing, MI, March 8, 2011. Oral presentation.

Cooper, M.J., G.A. Lamberti, and D.G. Uzarski. Monitoring ecosystem health in Great Lakes coastal wetlands: a basin-wide effort at the intersection of ecology and management. Entomological Society of America, Reno, NV, November 13-16, 2011. Oral presentation

Cooper, M.J., and G.A. Lamberti. Taking the pulse of Great Lakes coastal wetlands: scientists tackle an epic monitoring challenge. Poster session at the annual meeting of the National Science Foundation Integrative Graduate Education and Research Traineeship Program, Washington, D.C., May 2012. Poster presentation.

Cooper, M.J., J.M. Kosiara, D.G. Uzarski, and G.A. Lamberti. Nitrogen and phosphorus conditions and nutrient limitation in coastal wetlands of Lakes Michigan and Huron. Annual meeting of the International Association for Great Lakes Research. Cornwall, Ontario. May 2012. Oral presentation.

Cooper, M.J., G.A. Lamberti, and D.G. Uzarski. Abiotic drivers and temporal variability of Saginaw Bay wetland invertebrate communities. International Association for Great Lakes Research, 56th annual meeting, West Lafayette, IN. June 2013. Oral presentation.

Cooper, M.J., D.G. Uzarski, J. Sherman, and D.A. Wilcox. Great Lakes coastal wetland monitoring program: support of restoration activities across the basin. National Conference on Ecosystem Restoration, Chicago, IL. July 2013. Oral presentation.

Cooper, M.J. and J. Kosiara. Great Lakes coastal wetland monitoring: Chemical and physical parameters as co-variates and indicators of wetland health. US EPA Region 5 Annual Wetlands Program Coordinating Meeting and Michigan Wetlands Association Annual Meeting. Kellogg Biological Station, Hickory Corners, MI. October 2013. Oral presentation.

Cooper, M.J. Implementing coastal wetland monitoring. Inter-agency Task Force on Data Quality for GLRI-Funded Habitat Projects. CSC Inc., Las Vegas, NV. November 2013. Web presentation, approximately 40 participants.

Cooper, M.J. Community structure and ecological significance of invertebrates in Great Lakes coastal wetlands. SUNY-Brockport, Brockport, NY. December 2013. Invited seminar.

Cooper, M.J. Great Lakes coastal wetlands: ecological monitoring and nutrient-limitation. Limno-Tech Inc., Ann Arbor, MI. December 2013. Invited seminar.

Cooper, M.J., D.G. Uzarski, and V.J. Brady. A basin-wide Great Lakes coastal wetland monitoring program: Measures of ecosystem health for conservation and management. Great Lakes Wetlands Day, Toronto, Ont. Canada, February 4, 2014. Oral presentation.

Cooper, M.J., G.A. Lamberti, and D.G. Uzarski. Supporting Great Lakes coastal wetland restoration with basin-wide monitoring. Great Lakes Science in Action Symposium. Central Michigan University. April 4, 2014.

Cooper, M.J. Expanding fish-based monitoring in Great Lakes coastal wetlands. Michigan Wetlands Association Annual Meeting. Grand Rapids, MI. August 27-29, 2014.

Cooper, M.J. Structure and function of Great Lakes coastal wetlands. Public seminar of Ph.D. dissertation research. University of Notre Dame. August 6, 2014.

Cooper, M.J., D.G. Uzarski, and T.N. Brown. Developing a decision support system for protection and restoration of Great Lakes coastal wetlands. Biodiversity without Borders Conference, NatureServe. Traverse City, MI. April 27, 2015.

Cooper, M.J. and D.G. Uzarski. Great Lakes coastal wetland monitoring for protection and restoration. Lake Superior Monitoring Symposium. Michigan Technological University. March 19, 2015.

Cooper, M.J. Where worlds collide: ecosystem structure and function at the land-water interface of the Laurentian Great Lakes. Central Michigan University Department of Biology. Public Seminar. February 5, 2015.

Cooper, M.J. Where worlds collide: ecosystem structure and function at the land-water interface of the Laurentian Great Lakes. Sigurd Olson Environmental Institute, Northland College. Public Seminar. May 4, 2015.

Cooper, M.J., and D.G. Uzarski. Great Lakes coastal wetland monitoring for protection and restoration. Lake Huron Restoration Meeting. Alpena, MI. May 14, 2015.

Cooper, M.J., D.G. Uzarski, and V.J. Brady. Developing a decision support system for restoration and protection of Great Lakes coastal wetlands. Wisconsin Wetlands Association Annual Meeting. February 24-25, 2016. Green Bay, WI.

Cooper, M.J., Stirratt, H., B. Krumwiede, and K. Kowalski. Great Lakes Resilient Lands and Waters Initiative, Deep Dive. Remote presentation to the White House Council on Environmental Quality and partner agencies, January 28, 2016.

Cooper, M., Redder, T., Brady, V. and D. Uzarski. 2016. Developing a decision support tool to guide restoration and protection of Great Lakes coastal wetlands. Annual Meeting of the Wisconsin Wetlands Association, Stevens Point, WI. February. Presentation.

Cooper, M.J.. Nutrient limitation in wetland ecosystems. Wisconsin Department of Natural Resources, February 12, 2016, Rhinelander, WI.

Cooper, M.J., D.G. Uzarski and V.J. Brady. 2016. Developing a decision support system for restoration and protection of Great Lakes coastal wetlands. Wisconsin Wetlands Association Annual Meeting, Green Bay, WI. February 24-25. Oral Presentation.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Dahlberg, N., N.P. Danz, and S. Schooler. 2015. Integrating prior vegetation surveys from the St. Louis River estuary. Poster presentation at the 2015 Annual St. Louis River Summit, Superior, WI.

Dahlberg, N., N.P. Danz, and S. Schooler. 2017. 2012 Flood Impacts on St. Louis River Plant Communities. Poster presentation at St. Louis River Summit, Superior, WI.

Danz, N.P. 2014. Floristic quality of Wisconsin coastal wetlands. Oral presentation at the Wisconsin Wetlands Association 19th Annual Wetlands Conference, LaCrosse, WI. Audience mostly scientists.

Danz, N.P. Floristic Quality of Coastal and Inland Wetlands of the Great Lakes Region. Invited presentation at the University of Minnesota Duluth, Duluth, MN.

Danz, N.P., S. Schooler, and N. Dahlberg. 2015. Floristic quality of St. Louis River estuary wetlands. Oral presentation at the 2015 Annual St. Louis River Summit, Superior, WI.

Danz, N.P. 2016. Floristic quality of St. Louis River estuary wetlands. Invited presentation at the Center for Water and the Environment, Natural Resources Research Institute, Duluth, MN.

Danz, N.P. 2017. Connections Between Human Stress, Wetland Setting, and Vegetation in the St. Louis River Estuary. Oral presentation at the Wetland Science Conference, Stevens Point, WI.

Danz, N.P. 2017. 10 Things We Learned from Your Vegetation Data. Oral presentation at the St. Louis River Summit, Superior, WI.

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

Des Jardin, K. and D.A. Wilcox. 2014. Water chestnut: germination, competition, seed viability, and competition in Lake Ontario. New York State Wetlands Forum, Rochester, NY.

Dumke, J.D., V.J. Brady, J. Ciborowski, J. Gathman, J. Buckley, D. Uzarski, A. Moerke, C. Ruetz III. 2013. Fish communities of the upper Great Lakes: Lake Huron's Georgian Bay is an outlier. Society for Wetland Scientists, Duluth, Minnesota. 30 attendees, scientists and managers.

Dumke, J.D., V.J. Brady, R. Hell, A. Moerke, C. Ruetz III, D. Uzarski, J. Gathman, J. Ciborowski. 2013. A comparison of St. Louis River estuary and the upper Great Lakes fish communities (poster). Minnesota American Fisheries Society, St. Cloud, Minnesota. Attendees scientists, managers, and agency personnel.

Dumke, J.D., V.J. Brady, R. Hell, A. Moerke, C. Ruetz III, D. Uzarski, J. Gathman, J. Ciborowski. 2013. A comparison of wetland fish communities in the St. Louis River estuary and the upper Great Lakes. St. Louis River Estuary Summit, Superior, Wisconsin. 150 attendees, including scientists, managers, agency personnel, and others.

Dumke, J.D., V.J. Brady, J. Erickson, A. Bracey, N. Danz. 2014. Using non-degraded areas in the St. Louis River estuary to set biotic delisting/restoration targets. St. Louis River Estuary Summit, Superior, Wisconsin. 150 attendees, including scientists, managers, agency personnel, and others.

Dumke, J., C.R. Ruetz III, G.M. Chorak, R.A. Thum, and J. Wesolek. 2015. New information regarding identification of young brown and black bullheads. Oral presentation at the Annual Meeting of the Wisconsin Chapter of the American Fisheries Society, Eau Claire, Wisconsin. February 24-26. 150 attendees, including scientists, managers, agency personnel, and others.

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

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

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

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

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

Fraley, E.F. and D.G. Uzarski 2017. The relationship between vegetation and ice formation in Great Lakes coastal wetlands. 60th Annual Meeting of the International Association of Great Lakes Research. Detroit, MI. Poster.

Fraley, E.F. and D.G. Uzarski. 2016. The Impacts of Ice on Plant Communities in Great Lakes Coastal Wetlands. 7th Annual Meeting of the Michigan Consortium of Botanists, Grand Rapids, MI. October. Poster.

Gathman, J.P. 2013. How healthy are Great Lakes wetlands? Using plant and animal indicators of ecological condition across the Great Lakes basin. Presentation to Minnesota Native Plant Society. November 7, 2013.

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

Gilbert, J.M., N. Vidler, P. Cloud Sr., D. Jacobs, E. Slavik, F. Letourneau, K. Alexander. 2014. *Phragmites australis* at the crossroads: Why we cannot afford to ignore this invasion. Great Lakes Wetlands Day Conference, Toronto, ON, February 4, 2014.

Gilbert, J.M. 2013. Phragmites Management in Ontario. Can we manage without herbicide? Webinar, Great Lakes *Phragmites* Collaborative, April 5, 2013.

Gilbert, J.M. 2012. *Phragmites australis*: a significant threat to Laurentian Great Lakes Wetlands, Oral Presentation, International Association of Great Lakes Wetlands, Cornwall, ON, May 2012

Gilbert, J.M. 2012. *Phragmites australis:* a significant threat to Laurentian Great Lakes Wetlands, Oral Presentation to Waterfowl and Wetlands Research, Management and Conservation in the Lower Great Lakes. Partners' Forum, St. Williams, ON, May 2012.

Gil de LaMadrid, D., and N.P. Danz. 2015. Water depth optima and tolerances for St. Louis River estuary wetland plants. Poster presentation at the 2015 Annual St. Louis River Summit, Superior, WI.

Gnass Giese, E.E. 2015. Great Lakes Wetland Frog Monitoring. Annual Lower Fox River Watershed Monitoring Program Symposium at the University of Wisconsin-Green Bay, Green Bay, Wisconsin. April 14, 2015. Oral Presentation.

Gnass Giese, E.E. 2015. Wetland Birds and Amphibians: Great Lakes Monitoring. Northeastern Wisconsin Audubon Society meeting at the Bay Beach Wildlife Sanctuary, Green Bay, Wisconsin. February 19, 2015. Oral Presentation.

Gnass Giese, E.E., R.W. Howe, N.G. Walton, G.J. Niemi, D.C. Tozer, W.B. Gaul, A. Bracey, J. Shrovnal, C.J. Norment, and T.M. Gehring. 2016. Assessing wetland health using breeding birds as indicators. Wisconsin Wetlands Association Conference, Radisson Hotel & Convention Center, Green Bay, Wisconsin. February 24, 2016. Poster Presentation.

Gnass Giese, E., R. Howe, A. Wolf, and G. Niemi. 2017. Breeding Birds and Anurans of Dynamic Green Bay Coastal Wetlands. State of Lake Michigan Conference, Green Bay, Wisconsin. Oral Presentation. 8 November 2017.Gnass Giese, E.E., R.W. Howe, A.T. Wolf, N.A. Miller, and N.G. Walton. An ecological index of forest health based on breeding birds. 2013. Webpage: http://www.uwgb.edu/biodiversity/forest-index/

Gnass Giese, E.E., R.W. Howe, A.T. Wolf, N.A. Miller, and N.G. Walton. 2014. Using Bird Data to Assess Condition of Western Great Lakes Forests. Midwest Bird Conservation and Monitoring Workshop, Port Washington, Wisconsin. Poster Presentation. 4-8 August 2014.Gnass Giese, E.E. 2013. Monitoring forest condition using breeding birds in the western Great Lakes region, USA. Editors: N. Miller, R. Howe, C. Hall, and D. Ewert. Internal Report. Madison, WI and Lansing, MI: The Nature Conservancy. 44 pp.

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

Gurholt, C.G. and D.G. Uzarski. 2013. Into the future: Great Lakes coastal wetland seed banks. IGLR Graduate Symposium, Central Michigan University, Mt. Pleasant, MI. March.

Gurholt, C.G. and D.G. Uzarski. 2013. Seed Bank Purgatory: What Drives Compositional Change of Great Lakes Coastal Wetlands. 56th International Association for Great Lakes Research Conference, Purdue University, West Lafayette, IN. June.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Lamberti, G.A., D.G. Uzarski, V.J. Brady, M.J. Cooper, T.N. Brown, L.B. Johnson, J.J. Ciborowski, G.P. Grabas, D.A. Wilcox, R.W. Howe, and D. C. Tozer. An integrated monitoring program for

Great Lakes coastal wetlands. Society for Freshwater Science Annual Meeting. Jacksonville, FL. May 2013. Poster presentation.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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APPENDIX A

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

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2. http://www.wwmt.com/news/features/top-stories/stories/Snail-harmful-to-ducks-spreading-in-Great-Lakes-63666.shtml
3. http://fox17online.com/2014/12/16/gvsu-researchers-find-more-of-invasive-snail-species-in-lake-michigan/
4. http://www.ourmidland.com/news/cmu-scientists-identify-spread-of-invasive-species/article_e9dc5876-00f4-59ff-8bcd-412007e079e8.html
5. http://www.therepublic.com/view/story/4cde108b10b84af7b9d0cfcba603cf7a/MI--Invasive-Snails
6. http://media.cmich.edu/news/cmu-institute-for-great-lakes-research-scientists-identify-spread-of-invasive-species
7. http://www.veooz.com/news/qHv4acl.html
8. http://www.gvsu.edu/gvnow/index.htm?articleId=1E55A5C5-D717-BBE7-E79768C5213BB277
9. http://hosted2.ap.org/OKDUR/99dded7a373f40a5aba743ca8e3d4951/Article_2014-12-16-MI--Invasive%20Snails/id-b185b9fd71ea4fa895aee0af983d7dbd
10. http://whitehallmontague.wzzm13.com/news/environment/327493-my-town-waterfowl-killer-spreads-great-lakes-basin
11. http://www.timesunion.com/news/science/article/Snail-harmful-to-ducks-spreading-in-Great-Lakes-5959538.php
12. http://grandrapidscity.com/news/articles/gvsu-researchers-find-more-of-invasive-snail-species-in-lake-michigan
13. http://myinforms.com/en-us/a/8645879-gvsu-researchers-find-more-of-invasive-snail-species-in-lake-michigan/
14. http://usnew.net/invasive-snail-in-the-great-lakes-region.html
15. http://www.cadillacnews.com/ap_story/?story_id=298696&issue=20141216&ap_cat=2
16. http://theoryoflife.com/connect/researchers-track-invasive-9251724/
17. http://snewsi.com/id/1449258811
18. http://www.newswalk.info/muskegon-mich-new-scientists-say-742887.html
19. http://www.petoskeynews.com/sports/outdoors/snail-harmful-to-ducks-spreading-in-great-lakes/article_b94f1110-9572-5d18-a5c7-66e9394a9b24.html
20. http://www.chron.com/news/science/article/Snail-harmful-to-ducks-spreading-in-Great-Lakes-5959538.php

21. http://usa24.mobi/news/snail-harmful-to-ducks-spreading-in-great-lakes
22. http://www.wopular.com/snail-harmful-ducks-spreading-great-lakes
23. http://www.news.nom.co/snail-harmful-to-ducks-spreading-in-14203127-news/
24. http://www.mlive.com/news/muskegon/index.ssf/2014/12/hard_to_kill_invasive_faucet_s.html
25. http://wkar.org/post/researchers-eye-spread-invasive-faucet-snails
26. http://www.greenfieldreporter.com/view/story/4cde108b10b84af7b9d0cfcba603cf7a/MI--Invasive-Snails
27. http://www.natureworldnews.com/articles/11259/20141217/invasive-snails-killing-great-lake-birds.htm
28. http://www.wsbt.com/news/local/snail-harmful-to-ducks-spreading-in-great-lakes/30251286
29. http://www.wtkg.com/articles/wood-news-125494/invasive-and-deadly-snail-found-in-13073963
30. http://www.techtimes.com/articles/22378/20141218/invasive-snail-problem-in-great-lakes-difficult-to-deal-with-says-experts.htm
31. http://perfscience.com/content/214858-invasive-snails-kill-birds-great-lakes
32. http://www.hollandsentinel.com/article/20141216/NEWS/141219279
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37. http://www.seattlepi.com/news/science/article/Snail-harmful-to-ducks-spreading-in-Great-Lakes-5959538.php
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39. http://www.wilx.com/home/headlines/Invasive-Snail-Spreading-in-Great-Lakes-285933261.html
40. http://www.watertowndailytimes.com/article/20150119/NEWS03/150118434
41. http://howardmeyerson.com/2015/01/15/scientists-invasive-snail-more-prevalent-than-thought-poses-grave-danger-to-waterfowl/

MOCK-UP OF PRESS RELEASE PRODUCED BY COLLABORATING UNIVERSITIES.

FOR IMMEDIATE RELEASE: December 9, 2014

CONTACT: June Kallestad, NRRI Public Relations Manager, 218-720-4300

USEPA-sponsored project greatly expands known locations of invasive snail

DULUTH, Minn. – Several federal agencies carefully track the spread of non-native species. This week scientists funded by the Great Lakes Restoration Initiative in partnership with USEPA's Great Lakes National Program Office greatly added to the list of known locations of faucet snails (*Bithynia tentaculata*) in the Great Lakes. The new locations show that the snails have invaded many more areas along the Great Lakes coastline than anyone realized.

The spread of these small European snails is bad news for water fowl: They are known to carry intestinal flukes that kill ducks and coots.

"We've been noting the presence of faucet snails since 2011 but didn't realize that they hadn't been officially reported from our study sites," explained Valerie Brady, NRRI aquatic ecologist who is collaborating with a team of researchers in collecting plant and animal data from Great Lakes coastal wetlands.

Research teams from 10 universities and Environment Canada have been sampling coastal wetlands all along the Great Lakes coast since 2011 and have found snails at up to a dozen sites per year [See map 1]. This compares to the current known locations shown on the USGS website [see map 2].

"Our project design will, over 5 years, take us to every major coastal wetland in the Great Lakes. These locations are shallow, mucky and full of plants, so we're slogging around, getting dirty, in places other people don't go. That could be why we found the snails in so many new locations," explained Bob Hell, NRRI's lead macroinvertebrate taxonomist. "Luckily, they're not hard to identify."

The small snail, 12 – 15 mm in height at full size, is brown to black in color with a distinctive whorl of concentric circles on the shell opening cover that looks like tree rings. The tiny size of young snails means they are easily transported and spread, and they are difficult to kill.

According to the Minnesota Department of Natural Resources, the faucet snail carries three intestinal trematodes that cause mortality in ducks and coots. When waterfowl consume the infected snails, the adult trematodes attack the internal organs, causing lesions and hemorrhage. Infected birds appear lethargic and have difficulty diving and flying before eventually dying.

Although the primary purpose of the project is to assess how Great Lakes coastal wetlands are faring, detecting invasives and their spread is one of the secondary benefits. The scientific team expects to report soon on the spread of non-native fish, and has helped to locate and combat invasive aquatic plants.

“Humans are a global species that moves plants and animals around, even when we don’t mean to. We’re basically homogenizing the world, to the detriment of native species,” Brady added, underscoring the importance of knowing how to keep from spreading invasive species. Hell noted, “We have to make sure we all clean everything thoroughly before we move to another location.”

For more information on how to clean gear and boats to prevent invasive species spread, go to www.protectyourwaters.net.