Great Lakes Coastal Wetland Monitoring Program

Semiannual Progress Report
October 1, 2022 – March 31, 2023

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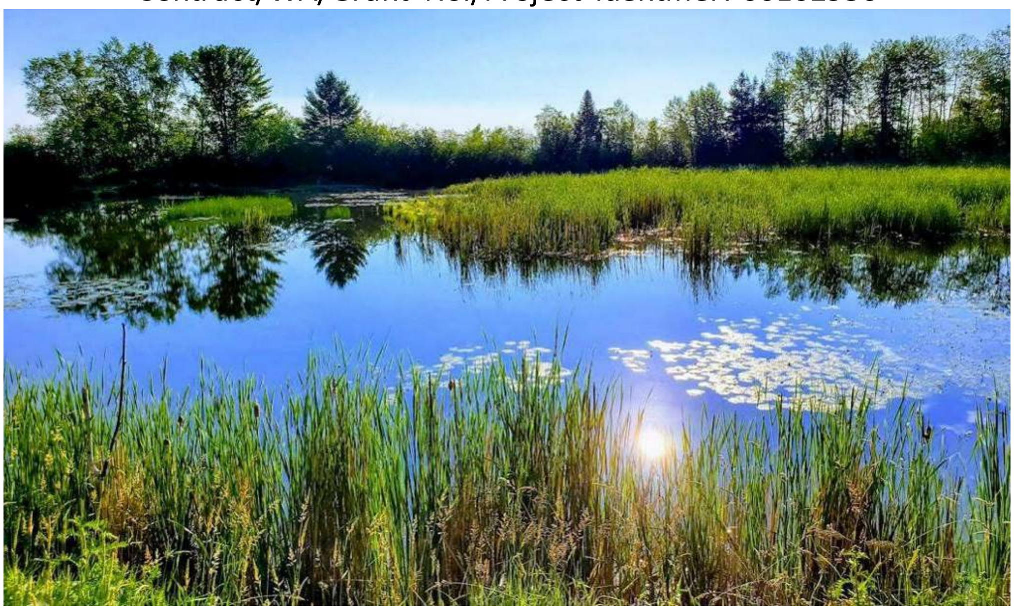

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TABLE OF CONTENTS

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 (2021-2015). This will be our first full sampling round as a sampling program rather than a project. During the second round (2016-2020) 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 sampling. In addition, we continue to support wetland restoration projects by providing data, information, and context.

SUMMARY OF SAMPLING SCHEDULE

Our first round of sampling (2011-2015), 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. Most of our project management team has not changed since our last report. In the Central Basin US team, Dr. Robert Howe, bird and anuran PI, has retired; he will continue working with the project as an emeritus professor, but the lead PI for birds and anurans for this area has been assumed by Erin Giese, who has been with the program for a decade.

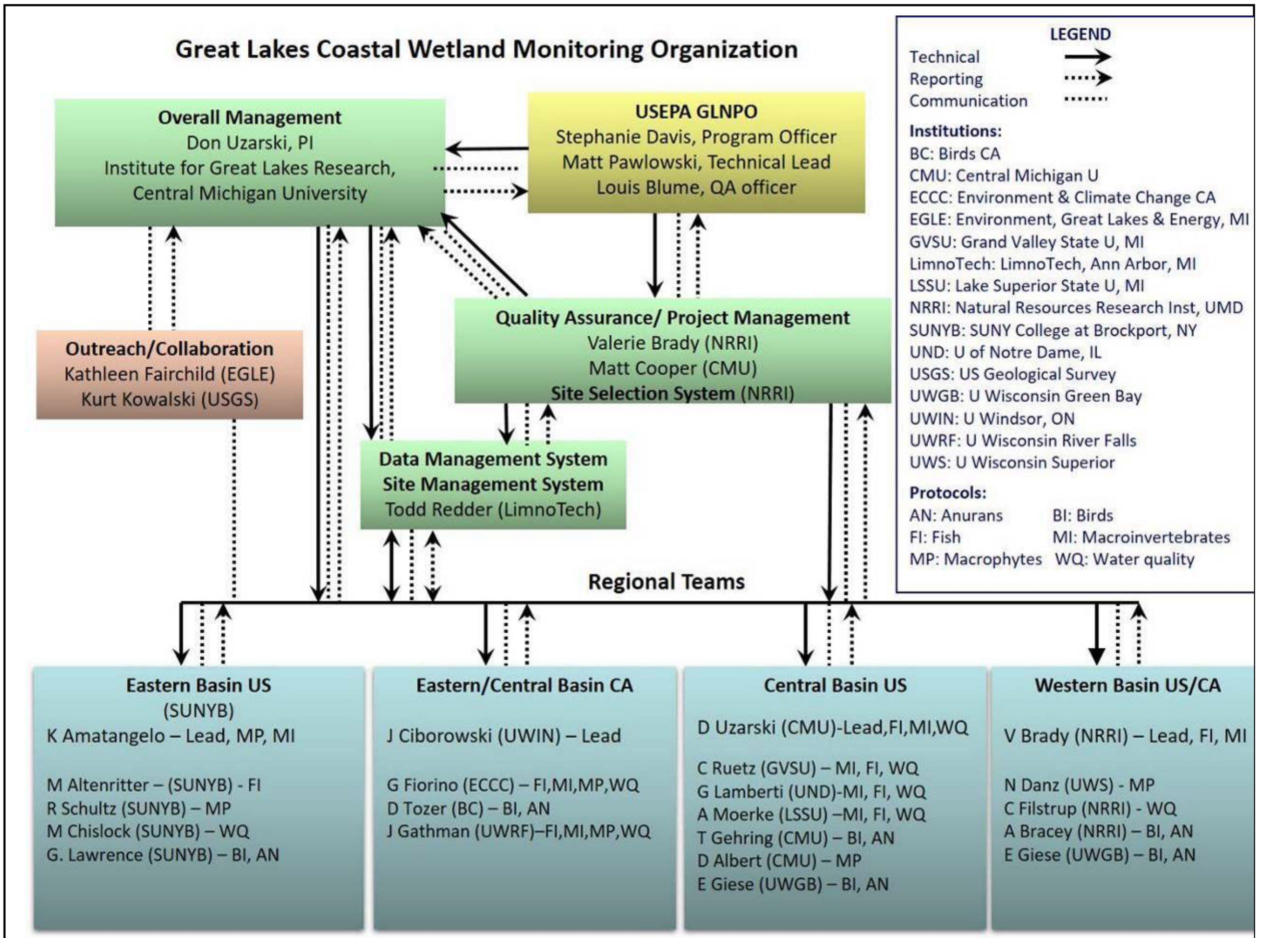

Figure 1. Current organizational chart for the program showing lines of technical direction, reporting, and communication separately.

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, 2022 – March 31, 2023)		Project Status** (Feb. 2021 – Jan. 2026)	
		Number	Percent	Number	Percent
4.1.3	Number of Great Lakes coastal wetlands assessed for biotic condition	0	0	364	40%

* Sampling is completed in the summer and reported in the fall report
** (Not Started; Started; Paused; 25% Completed; 50% Completed; 75% Completed; 95% Completed; and 100% Completed)

SITE SELECTION

Year thirteen site selection was completed in March 2023. We have completed our 5-year sampling scheme twice (round 1: 2011-2015; round 2: 2016-2020) and are starting the third 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. Most of the wetlands to be sampled this year (2023) were previously sampled in 2013 and 2018.

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 and again for 2023.

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).

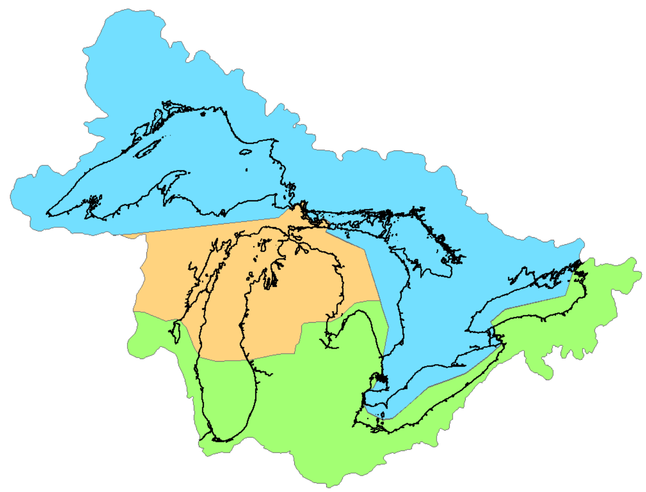

Figure 2. Divisions of lakes into regions. Note that stratification is by region *and* lake, so northern Lake Erie is not in the same region as Lake Superior, etc.

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; site was on tribal land with access denied due to Covid; site could not be sampled for some other Covid-related issue, etc.).

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.

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 in 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.

2023 SITE SELECTION

For 2023, 209 sites have been selected for sampling (Figure 3). Of these, 13 are benchmark sites. Another 13 sites are re-sample sites and 19 are pre-sample sites, which will be re-sample sites next year (2024). 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 2023 site list.

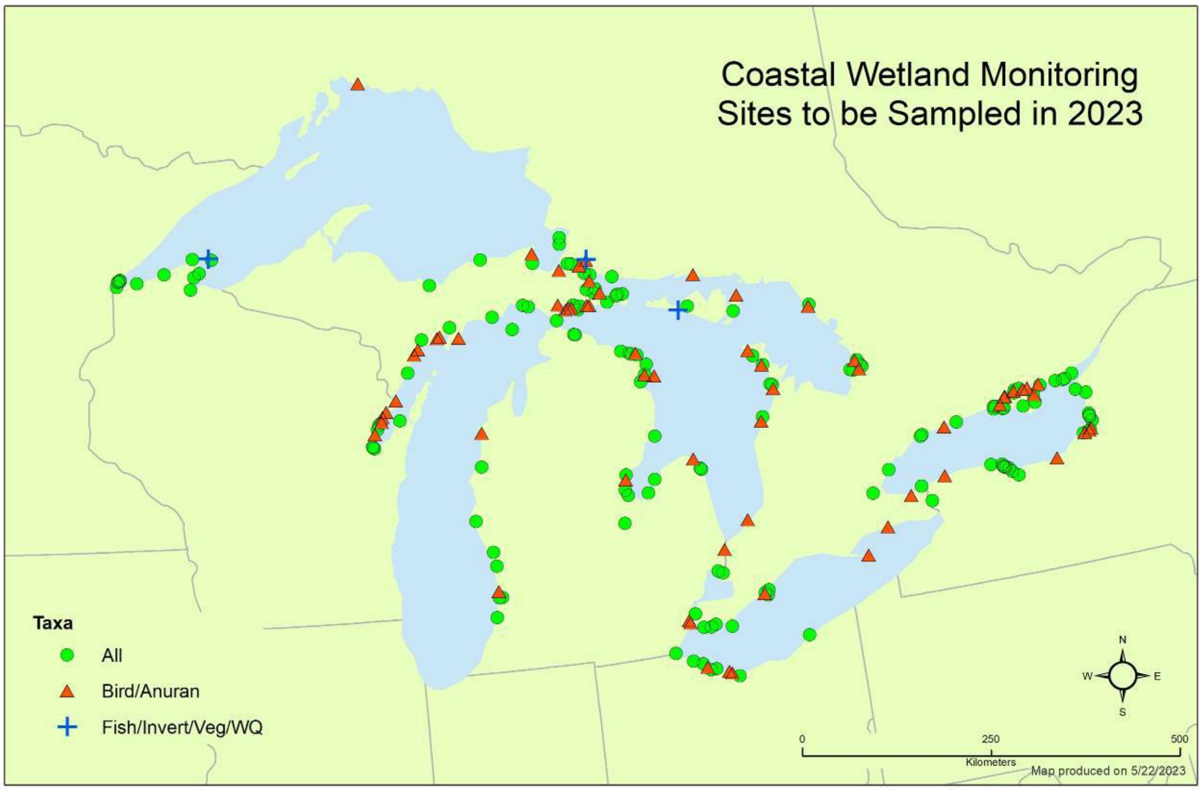

Figure 3. Locations of the 209 Great Lakes coastal wetlands to be sampled in 2023, color-coded by taxonomic groups. Sites assigned only to bird and anuran crews (due to their greater sampling capacity) are shown with a red triangle.

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 209 Great Lakes coastal wetlands to be sampled in 2023, 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 requested and were granted additional funding to completely re-construct the Site Management System. Funding was not received in time to complete the rebuild of the Site Management System before the need to be using the system to generate the 2023 site list. This necessitated us again relying on the old system. We struggled to get the old system to generate the 2023 site list and correctly assign sites to teams based on the areas each team can sample. We did ultimately get the code to work and a 2023 site list was generated in time for team leaders to begin seeking sampling permits. The 2022 system crash and 2023 struggles emphasized the critical importance of this system to the running of our program.

Using the additional funding granted us by USEPA, we are in the process of completely reconstructing the Site Management System, which will be housed on the servers at Central Michigan University. We plan to be testing the new system this fall and switch over to it during the winter of 2023/2024, when there is little use of the site system.

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. Additional training on data entry is provided as needed.

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 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 (2011-2022, 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). But teams sampled 188 wetlands in 2022 (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. Now that water levels are moderating, crews faced fewer sampling difficulties in 2021 and 2022. However, all of 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%
2022	128	68%	29,625	82%
US total Round 3	**250**	**69%**	**54,359**	**83%**

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. Thankfully, the 2022 field season was much more normal for border crossings and we have high hopes for the 2023 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%
2022	59	32%	6,637	18%
CA total Round 3	**112**	**31%**	**10,901**	**17%**
Overall Totals Round 1	**1010**		**151,446**	
Overall Totals Round 2	**978**		**164,312**	
Overall Totals Round 3	**362**		**65,260**	

One final note about the 2022 field season: Bird and anuran crews faced a very cold, late spring across much of the region, compressing fieldwork into a shorter timeframe. We expect this will be true at least of the upper Great Lakes for 2023.

BIOTIC COMMUNITIES AND CONDITIONS (BASED ON 2011-2022 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 average about 25 bird species; some sampled benchmark sites had only a few bird species, but richness at high quality sites was as great as 54 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 2022, using only the latest year sampled for each wetland.

Country	Site count	Mean	Max	Min	St. Dev.
Birds					
Can.	268	27.0	54	5	9.7
U.S.	482	22.4	54	2	9.2
Anurans					
Can.	218	4.6	8	0	1.6
U.S.	431	4.2	8	1	1.3

Bird and anuran data in Great Lakes coastal wetlands by lake (Table 9) shows that wetlands on most lakes had an average number of bird species in the low-mid twenties. The greatest number of bird species at a wetland occurred on lakes Michigan and Ontario, with Lake Huron 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 2022, using only the latest year sampled for each wetland.

	Birds				Anurans			
Lake	**Sites**	**Mean**	**Max**	**Min**	**Sites**	**Mean**	**Max**	**Min**
Erie	92	24.8	49	5	86	3.9	7	1
Huron	228	23.6	52	4	195	4.4	8	0
Michigan	133	23.8	54	2	121	4.1	7	1
Ontario	200	25.4	54	9	169	4.8	8	1
Superior	97	22.1	41	5	78	3.9	7	1

An average of 9 to 12 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 5. An encouraging sign is that there are wetlands in which no non-native fish species were caught in fyke nets, although some non-native fish are adept at net avoidance (e.g., common carp).

Table 10. Total fish species in wetlands, and non-native species; summary statistics by country for sites sampled from 2011 through 2022, using only the latest year sampled for each wetland.

Country	**Sites**	**Mean**	**Max**	**Min**	**St. Dev.**
Overall					
Can.	155	9.3	24	1	3.9
U.S.	267	12.3	28	3	4.6
Non-natives					
Can.	155	0.8	5	0	0.9
U.S.	267	0.9	5	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.

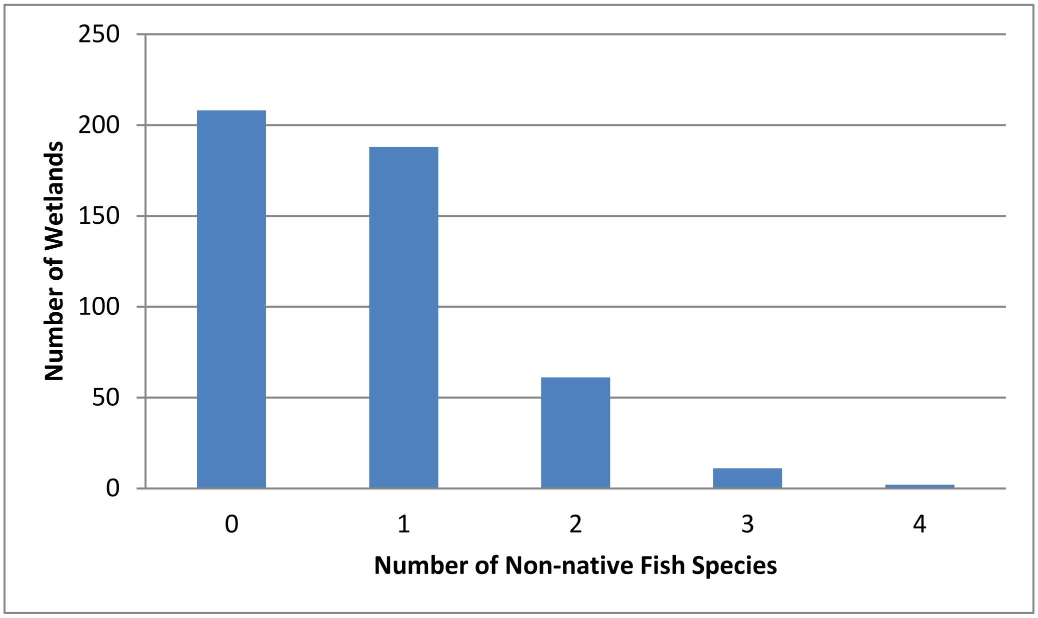

Figure 5. Number of Great Lakes coastal wetlands containing non-native fish species. Data from 2016 through 2020.

Total fish species did not differ greatly by lake, averaging 11-12 species per wetland (Table 11). Lakes Erie and Michigan had the most species of fish in a wetland, 27-28 species; the other lakes had a maximum of 20-22 species in a wetland. Because sites in need of restoration are included, some of these sites had very few fish species, as low as only a single species. 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. Our single-night net sets do not catch all fish species in wetlands, and some species are quite adept at avoiding passive capture gear. 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 2022, using only the latest year sampled for each wetland.

		Fish (Total)			Non-native		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	54	11.9	28	4	1.6	5	0
Huron	153	11.1	22	1	0.6	2	0
Michigan	66	12.2	27	4	1.0	4	0
Ontario	96	10.0	20	4	0.9	3	0
Superior	53	11.2	21	3	0.8	4	0

The average number of macroinvertebrate taxa (taxa richness) per site was about 36 (Table 12), but some wetlands had nearly 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 2022, using only the latest year sampled for each wetland.

Country	Sites	Mean	Max	Min	St. Dev.
Overall					
Can.	176	36.7	65	18	9.8
U.S.	312	35.4	69	12	12.2
Non-natives					
Can.	176	0.7	4	0	0.9
U.S.	312	0.8	5	0	1.0

There is little variability among lakes in the mean number of macroinvertebrate taxa per wetland, with averages ranging from 32-40 taxa with lakes Ontario and Erie having slightly lower averages than the upper lakes (Table 13). The maximum number of invertebrate taxa was lowest in Lake Ontario wetlands (57) with the most invertebrate-rich wetlands in the other lakes having a maximum of nearly 70 taxa. Wetlands with the fewest taxa tend to be 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 2022, using only the latest year sampled for each wetland.

		Macroinvertebrates (Total)			Non-native		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	60	34.4	69	12	1.2	5	0
Huron	172	37.0	65	12	0.5	4	0
Michigan	82	36.0	66	14	1.1	4	0
Ontario	111	32.2	57	16	0.7	3	0
Superior	63	40.4	66	15	0.3	2	0

There is little variability among lakes in non-native macroinvertebrate taxa occurrence, although Lake Superior and Lake Huron 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.

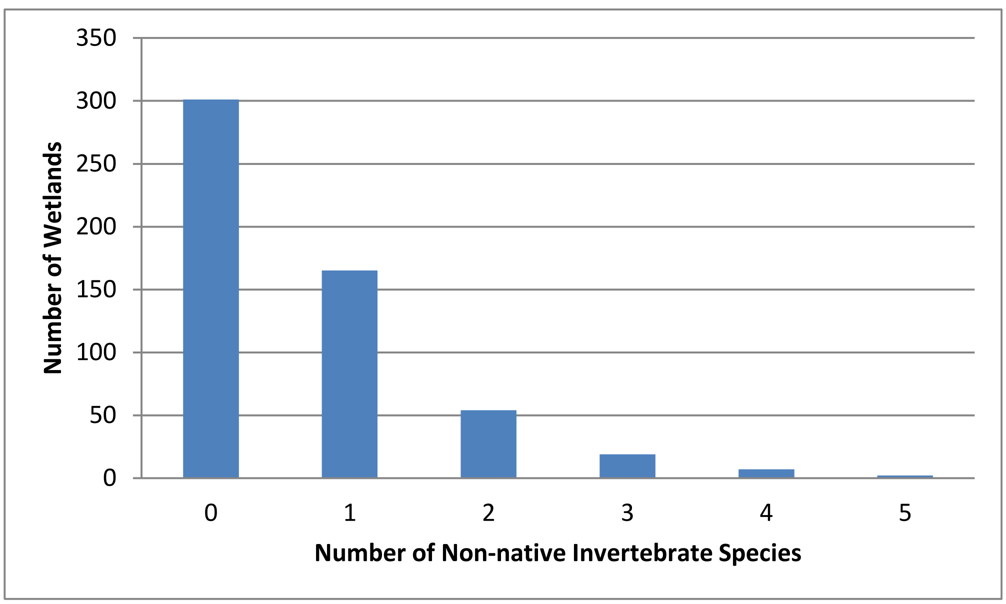

Figure 5. Number of Great Lakes coastal wetlands containing non-native invertebrate species. Data from 2016-2020 .

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

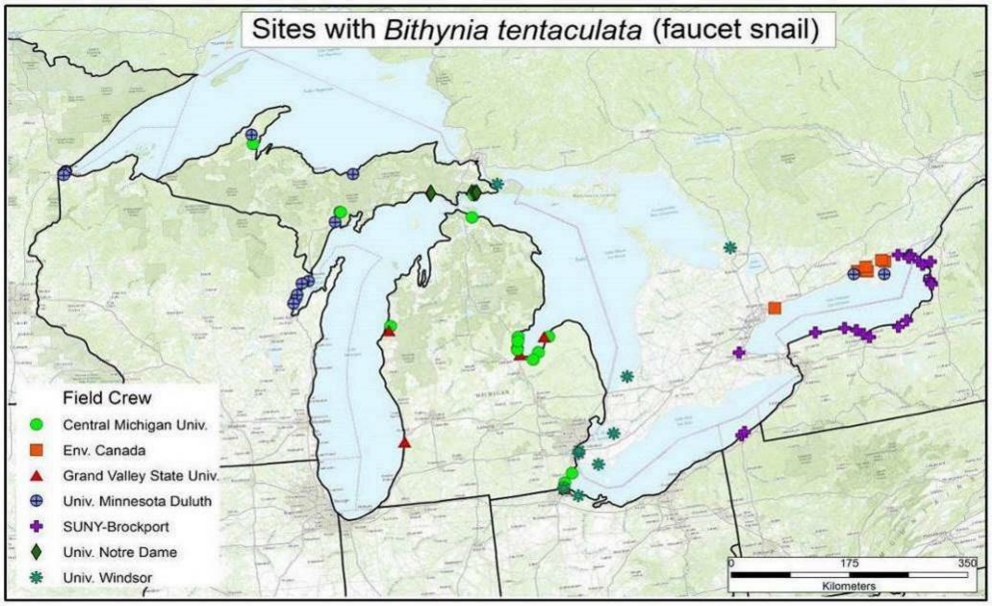

Figure 7. Locations of *Bithynia tentaculata* found by CWM crews, 2011 - 2013.

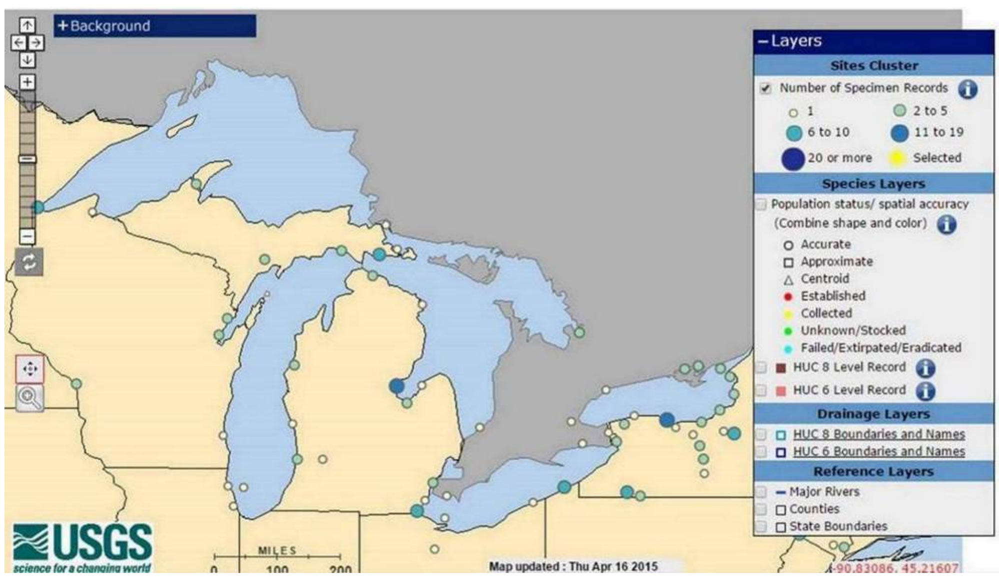

Figure 8. Locations of *Bithynia tentaculata* in USGS NAS website AFTER our project provided additional locations where they were collected; compare to Figure 6.

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 nearly 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. Data from 2011 through 2022, using only the latest year sampled for each wetland.

Country	Site count	Mean	Max	Min	St. Dev.
Overall					
Can.	181	36.6	88	5	17.1
U.S.	321	38.9	100	0	17.7
Non-native					
Can.	181	4.9	13	0	3.0
U.S.	321	3.9	21	0	3.1

Lake Erie wetlands had by far the lowest mean number of macrophyte species (24, Table 15), with the other lakes' wetlands having higher mean numbers of species (34-42, 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 (6) and Lake Huron had the highest maximum number with 21. There are wetlands on all lakes but Lake Ontario 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 2022, using only the latest year sampled for each wetland.

		Macrophytes (Total)			Non-native		
Lake	**Sites**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Erie	58	24.2	61	5	5.3	14	0
Huron	175	42.4	100	3	3.1	21	0
Michigan	80	37.0	72	7	3.9	11	0
Ontario	127	41.0	91	8	7.0	16	1
Superior	62	34.5	64	0	1.4	6	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.

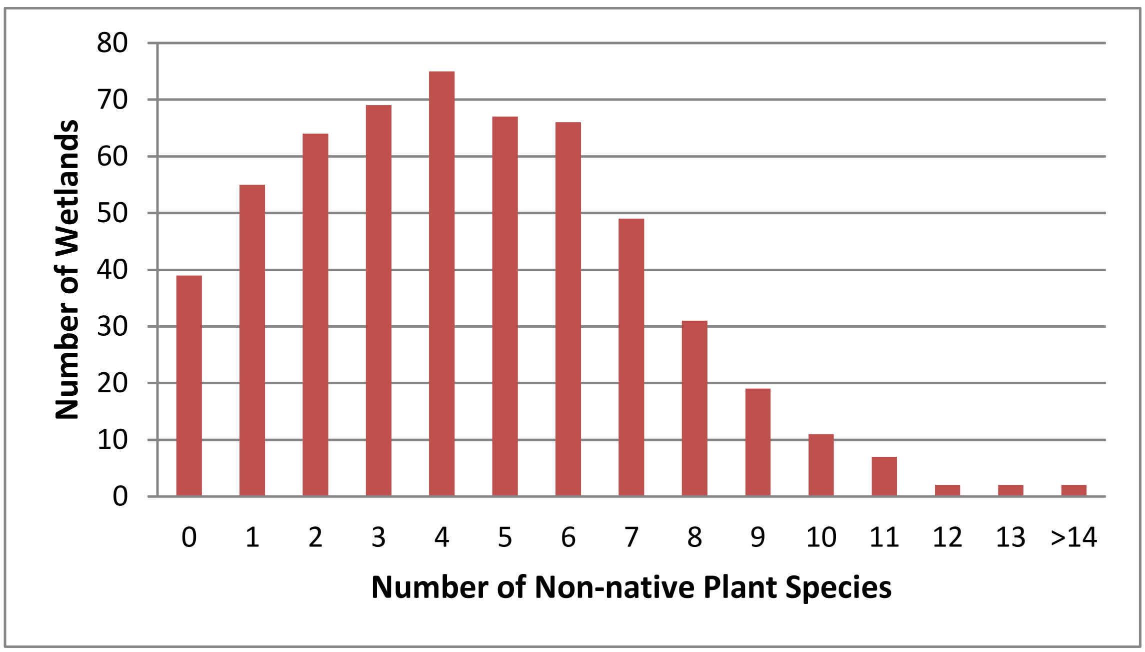

Figure 9. Number of Great Lakes coastal wetlands containing invasive plant species based on 2016 through 2020 data.

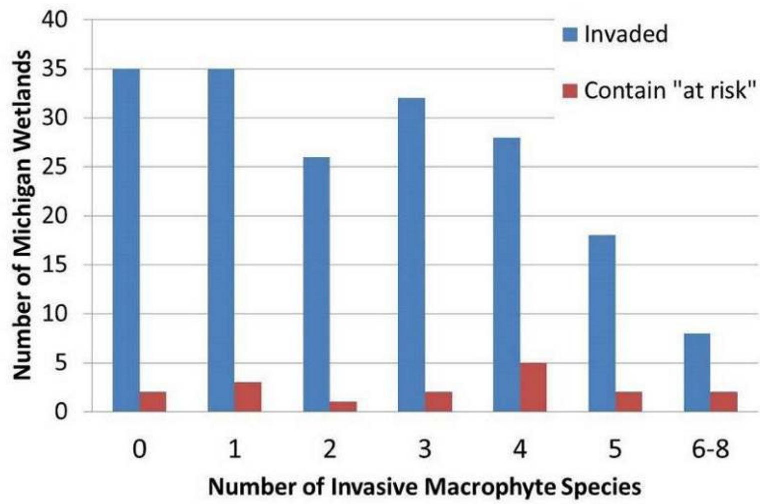

Figure 10. Number of state of Michigan Great Lakes coastal wetlands containing both invasive plant species and “at risk” plant species, based on 2011 through 2014 data.

We created a map of invasion status of Great Lakes coastal wetlands using all invasive species data we collected through 2014 for all taxonomic groups combined (Figure 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.

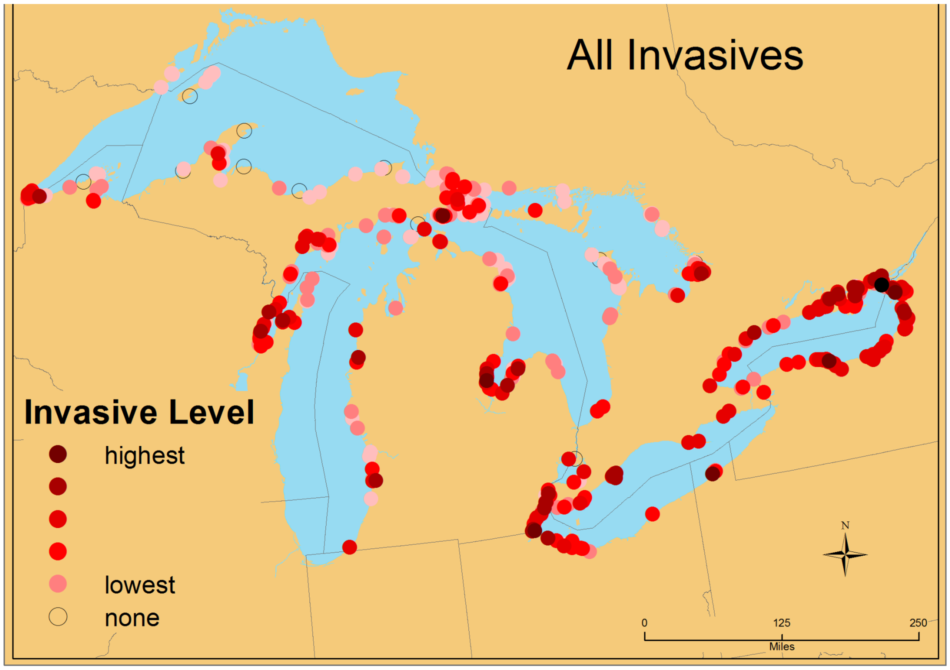

Figure 11. Level of "invadedness" of Great Lakes coastal wetlands for all non-native taxa combined across all taxonomic groups, based on data from 2011-2014.

WETLAND CONDITION (based on 2011 – 2022 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 uses C scores for wetland species, among other metrics.

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.

New with this report (spring 2023) we are debuting a new vegetation-based IBI (Dybiec et al. 2020) which the draft IBI developed by Dr. Dennis Albert during the early stage of Great Lakes-wide biotic sampling for the USEPA (Albert 2008). The structure and many of the metrics of the new IBI are shared with the original, but the new IBI has increased the number of metrics used and refined the metrics for the submergent zone. The original submergent zone metrics were difficult to compute.

Both the old and new IBIs were calculated by vegetation zone, making it possible to identify the source of degradation in a wetland. In many cases the impact of land or water use can result in the level of degradation in one zone being very different than that in other zones, and identifying the degraded zones can facilitate more effective restoration efforts. The advantage of Dybiec et al. (2020) is that the zonal scores are more easily accessible than in the original IBI, and the submergent zone metrics are much more dependable and easier to compute. The zonal scores in both IBIs are combined to create a site-wide score, and these site-wide scores are what are used in individual lake (Erie, Huron, Michigan, Ontario, and Superior) comparisons and long-term tracking of wetland quality change for the individual lakes and the entire Great Lakes.

The scores of the old and new IBIs are strongly correlated for the site-wide scores, with R^2 = 0.65 for the entire plant database between 2011-2022 (Figure 13), with a similar R^2 = 0.63 for the high-water years of 2021-2022 (Figure 14). It appears that the IBI scores of some of the most open lacustrine sites that had the highest IBI scores (5) with the original IBI, scored much lower with the new IBI, especially during high-water years of 2021 and 2022. Our interpretation is that the new IBI is providing a more effective evaluation of the submergent zone, a weakness in the original IBI.

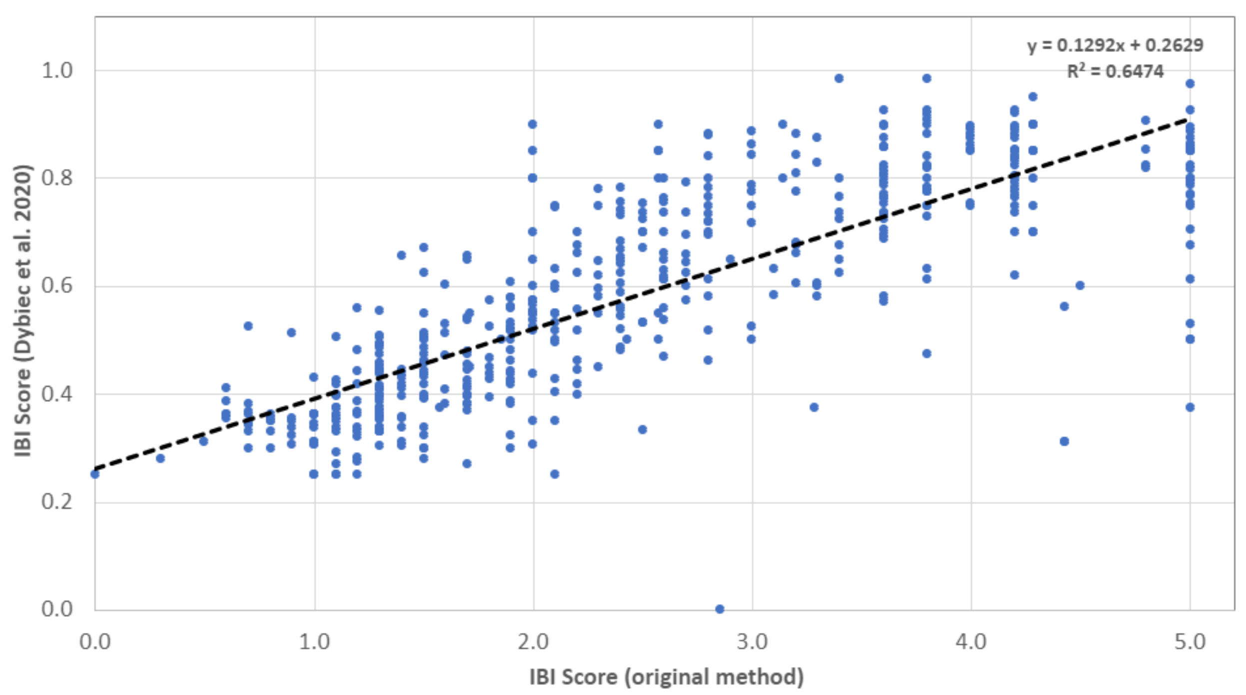

Figure 13. Comparison of original vs. revised vegetation IBI (2011-2022).

Using the new IBI, the site-wide scores appear to be slightly lower for the most degraded sites (old IBI scores <2) and slightly higher for the less degraded sites (old IBI scores >2). This is likely the result of adding metrics based on specific taxa, *Carex* spp. for the Wet Meadow, and Cyperaceae cover for the emergent zone, both taxonomic groups well represented in less degraded wetlands and often groups missing from highly degraded wetlands.

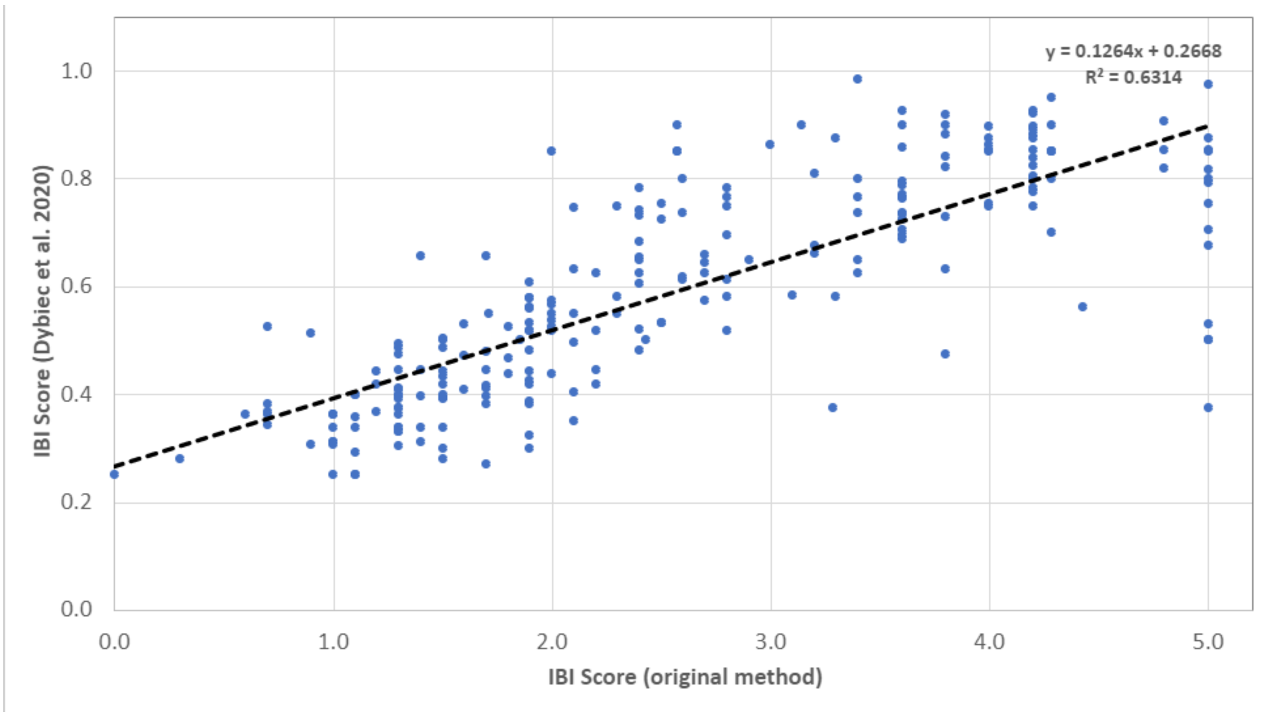

Figure 14. Comparison of original vs. revised vegetation IBI (2021-2022 data only).

Lake-wide comparison of the old and new IBIs produce similar results. The order of lake-wide quality remains the same, with Lake Superior having the highest IBI scores, followed in order by Lake Huron, Lake Michigan, Lake Ontario, and Lake Erie.

The map (Figure 15) 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.

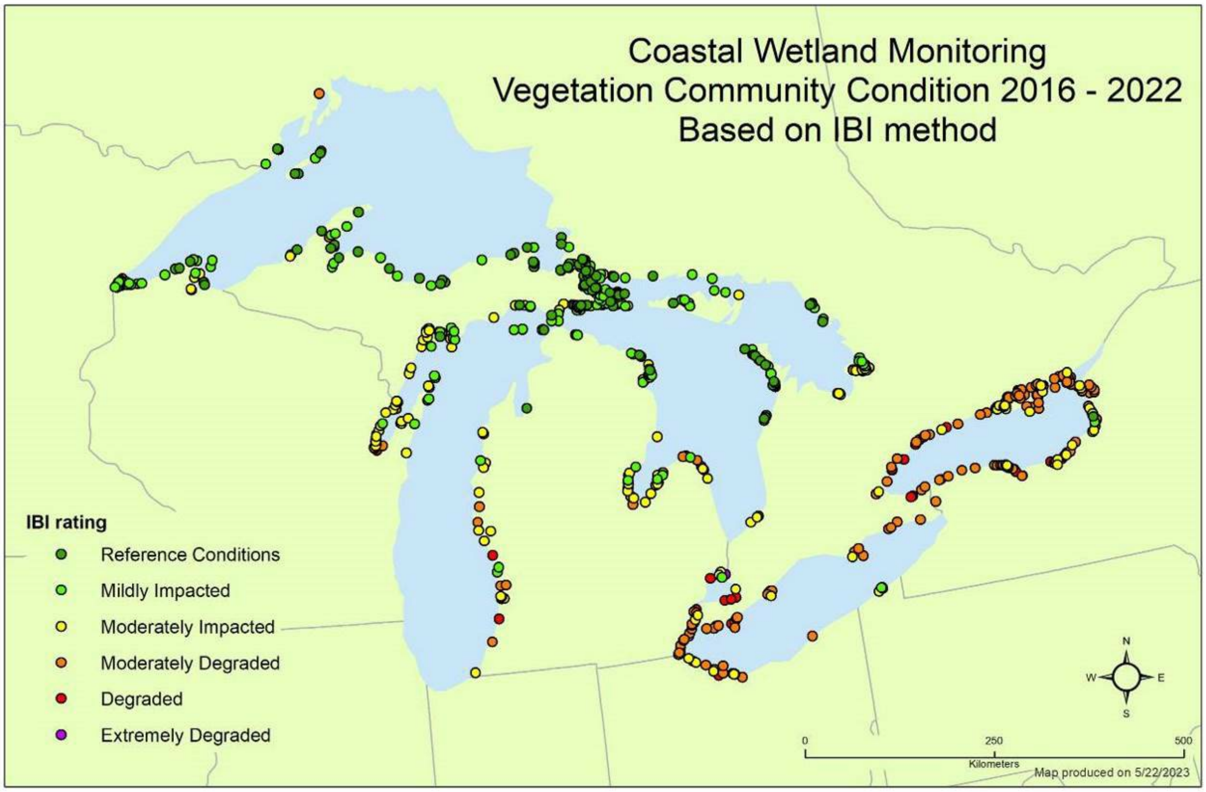

Figure 15. Condition of coastal wetland vegetation at sites across the Great Lakes. Circle color indicates vegetation community quality. Map shows IBI for the most recent year sampled for each site. IBI newly updated for 2023; see text for description.

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 16). 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.

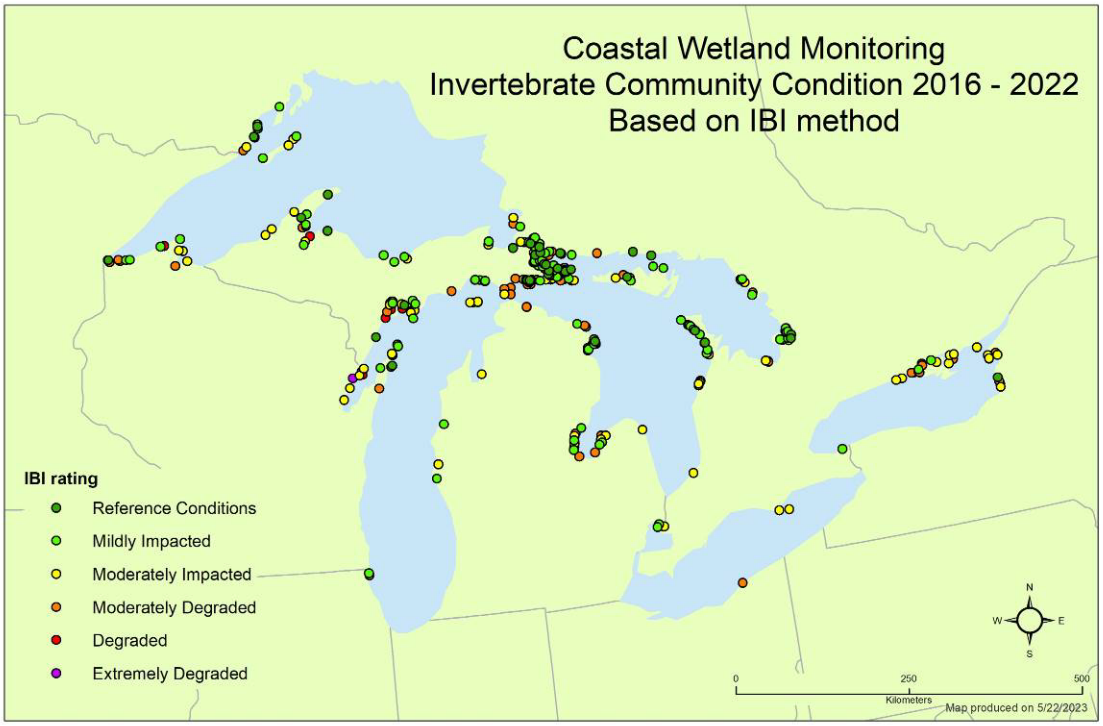

Figure 16. Condition of coastal wetland macroinvertebrate communties at sites with bulrush or wet meadow zones. Map shows IBI for the most recent year sampled for each site.

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 17). 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.

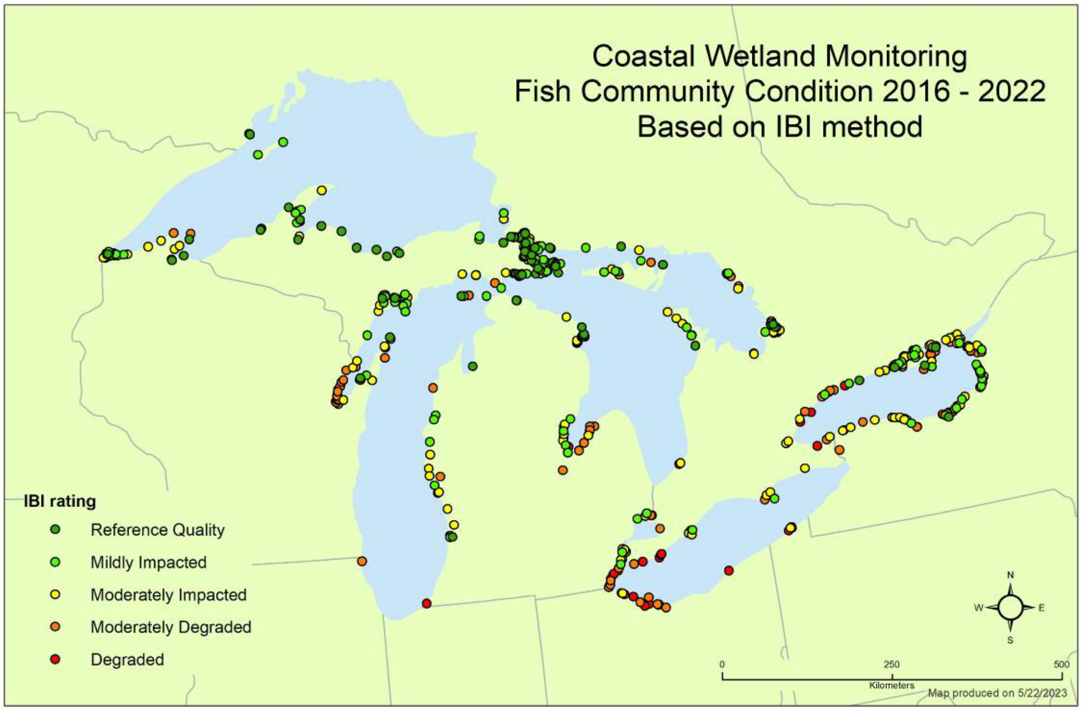

Figure 17. Condition of coastal wetland fish communties at sites with bulrush, cattail, lily, or submerged aquatic vegetation zones. Map shows IBI for the most recent year sampled for each site.

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.

The IEC2 metric replaces the likelihood metric (Index of Ecological Condition, Howe et al. 2007a, 2007b, Gnass Giese et al. 2015, Jung et al. 2020, and Howe et al. 2021) used during previous years of the Great Lakes Coastal Wetland Monitoring Program. When the number of species is relatively small, IEC estimates are often unstable and tend to gravitate to IEC = 0; likewise, when a moderate number of the most sensitive ("high quality") species are present, the index trends to IEC = 10. Values of the new IEC2 are highly correlated with the original IEC (Figure 18), but they do not exhibit convergence at IEC=0 and IEC=10, yielding a distribution of values that is nearly normally distributed (Figure 19). However, this means that there are fewer sites in the two best condition categories and it is very important that only the new IEC2 scores are used for sites. Scores for all sites have been recalculated using this new metric and their scores are provided.

Like the original IEC, the new metric (IEC2) is highly correlated with species richness (Figure 20), but it "weighs" species according to 1) their sensitivity to wetland disturbance and 2) their likelihood of occurrence and detection in highest quality wetlands. Species weights are derived from parameters of BIOTIC RESPONSE (BR) FUNCTIONS representing each of the targeted bird species or species groups, identical to the approach underlying the original IEC (Howe et al. 2007a, 2007b, Gnass Giese et al. 2015). Our BR functions are based on a best-fit normal distribution depicting the response of bird species or species groups to a multivariate gradient representing wetland area and the "human footprint" in the landscape surrounding the wetland Elliott (2019).

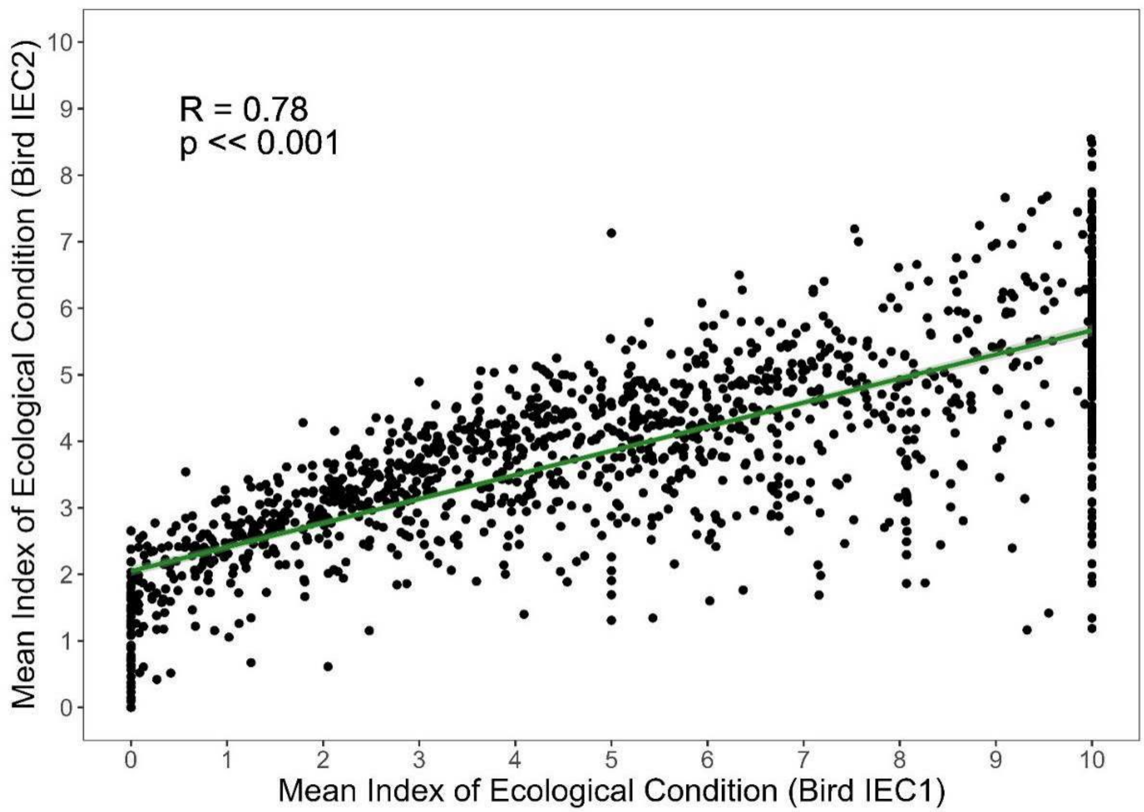

Figure 18. Correlation between the original Index of Ecological Condition (IEC1) and the new, much simpler metric, IEC2, for coastal wetland birds. Symbols (black dots) represent 1,909 wetland sites sampled 2011-2021. At wetlands where two or more points were sampled, the IEC values plotted are the mean IEC1 and IEC2 of all points. Note that disproportionate numbers of values occur at IEC1 = 0 and IEC1 = 10, an undesirable artifact that does not exist for IEC2.

BR functions are estimated using a maximum likelihood algorithm written by Robert Howe and Nicholas Walton in the R statistical computing environment (R Core Team 2023). Variables used to derive the "human footprint" include wetland size, % developed land and roads within 2 km of the wetland's center, % agricultural land within 2 km, % developed/agricultural land in the watershed flowing into the wetland, and human population within the watershed. Note: BR functions resemble the pre-determined COEFFIENTS OF CONSERVATISM often used for plant species indicator metrics (Bourdaghs et al. 2006), although our BR functions are an empirically derived, quantitative functional response rather than a subjective number assigned by experts.

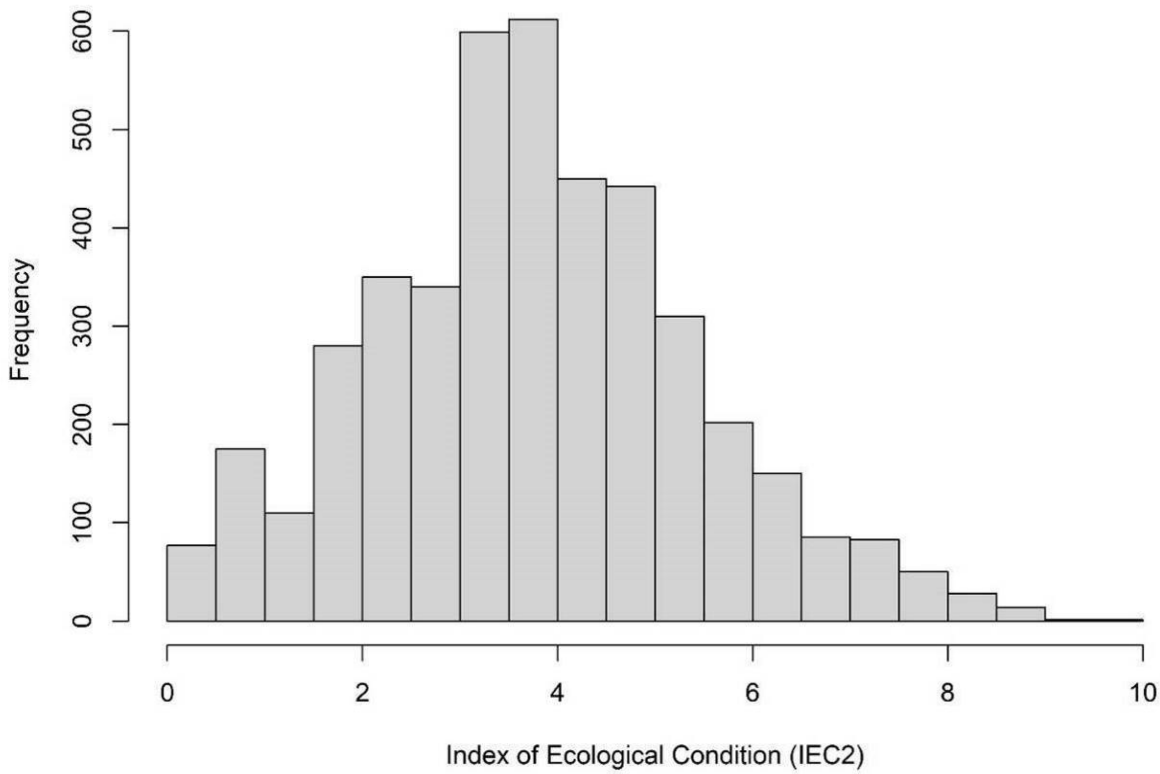

Figure 19. Distribution of IEC2 values from 4,369 point counts between 2011-2022. Although the theoretical range of IEC2 values ranges from 0-10, the median value of IEC2 = 3.726 (mean=3.758), illustrating the tendency of this metric to fall in the lower portion of the 0-10 scale. IEC2 values of 4.79 or higher represent high quality bird assemblages in the upper quartile (25%) of all point samples.

Weights for each species or species group are calculated as the product of two parameters: 1) the mean of the BR function and 2) the value of the BR function when the reference (environmental) gradient = 10. The BR function mean reflects the sensitivity of the species to the reference gradient; the more sensitive the species, the larger will be the mean. The shape of BR functions might reflect normal distribution functions whose means extend beyond the limits (0-10) of the reference gradient (Gnass Giese et al. 2015). The second parameter reflects the probability of encountering the species at highest quality sites, influenced by the ubiquity (commonness) of the species and the probability of detecting individuals when the species is present. This parameter effectively imposes a penalty for bird assemblages where common wetland species are absent; the absence of rarer species does not reduce the metric as significantly. The value of IEC2 is the sum of weights for all species present at the wetland during the two seasonal point counts, scaled from 0 (when no species are present) to 10 (when all species are present except those with negative weights).

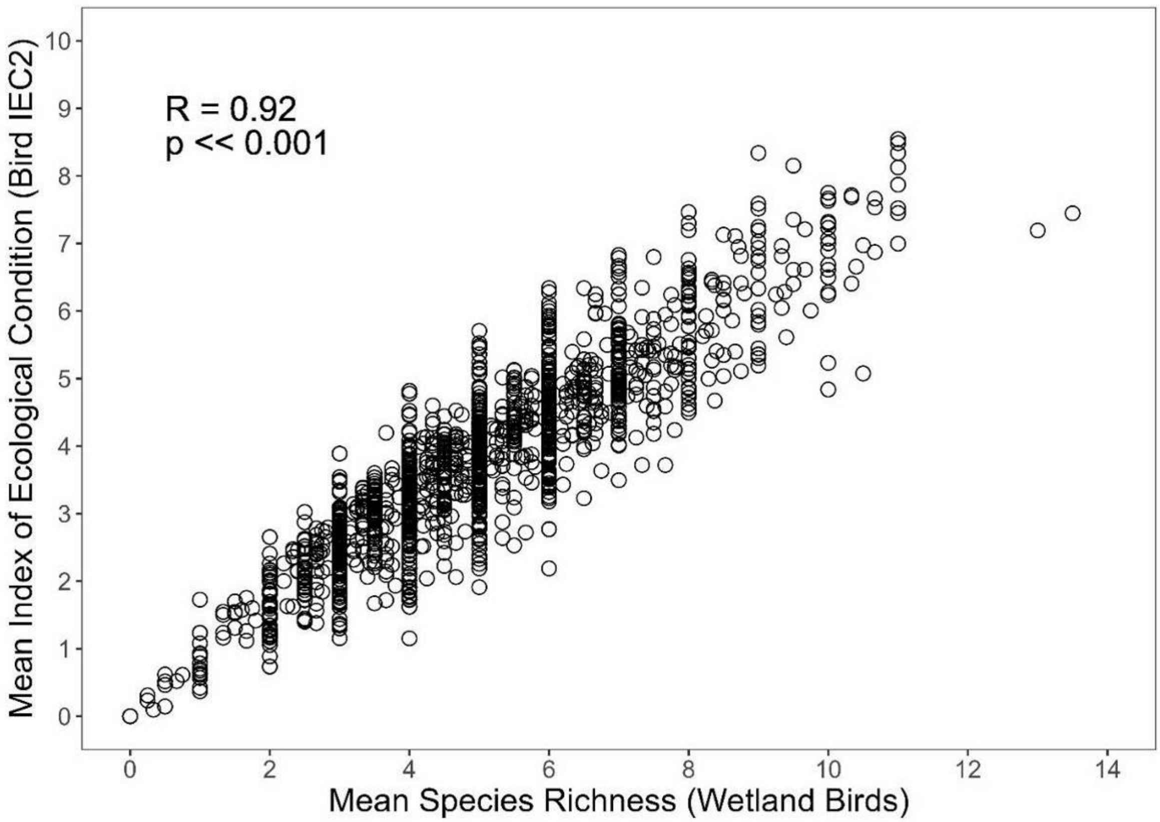

Figure 20. . Relationship between species richness (number of bird species/taxa) and the Index of Ecological Condition 2 (IEC2). Points (open circles) represent wetland sites (n = 1947) sampled between 2015-2022. Note that for a given number of bird species (e.g. = 4), a point may have different values of IEC2 depending on the composition of species/taxa; points with a high IEC2 were characterized by species/taxa with higher weights (i.e., higher “quality” species).

IEC2 calculations for birds include one species with a negative weight, European Starling (Sturnus vulgaris, abbreviation = EUST). The negative weight reflects this species’ monotonically negative response to the environmental gradient; in other words, it is most common at the lowest quality sites and least common at the highest quality sites. The maximum IEC2 condition ($W_{(max)}$) therefore occurs where all species/species groups are present except EUST, whose presence lowers the calculated index.

Like the environmental reference gradient, IEC2 values can range from 0 (most disturbed condition with lowest quality species assemblage) to 10 (least disturbed site with the highest quality species assemblage).

In addition to its simplicity, the IEC2 metric retains several qualities that make it a desirable biotic indicator. High scores are attained when the target site supports a broad range of functional taxonomic groups, including species that represent the full gradient of coastal wetland zones from coastal marsh (preferred by piscivores like Pied-billed Grebe) to seasonally flooded wet meadows (suitable for species like Sandhill Crane and Sedge Wren). The use of a limited set of indicator species and a fixed-effort sampling protocol also eliminates or at least reduces the influence of sampling effort, which can be problematic for unconstrained

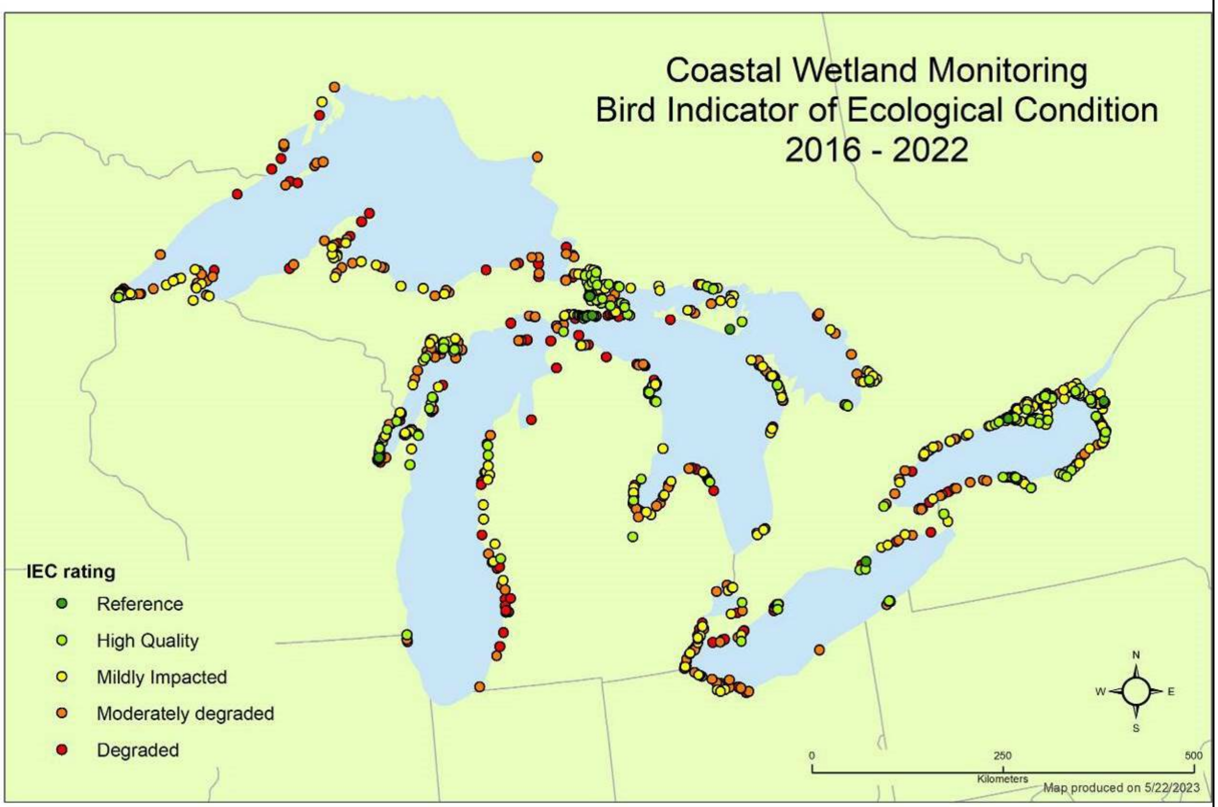

Figure 21. Condition of coastal wetland bird communties. This indicator is based on the IEC method (see text) using data collected primarily between 2016 and 2022, with data from 2011-2015 used to create the the baseline for the indicator but only used to calculate the actual wetland condition at a site if no other data were available.

application of metrics like the Floristic Quality Index or other indices that are correlated with species richness. Finally, the design of this metric creates the possibility that a comprehensive index could combine field data from birds, anurans, plants, and other taxonomic groups if objective species weights are available.

Note that high quality and reference values occur in all regions (Figure 21), suggesting that quality coastal wetlands for birds are widely distributed across the Great Lakes.

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*) are seldom observed. 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 (American toad or Fowler's Toad, *Anaxyrus spp.*; gray treefrogs, *Dryophytes* spp.; 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*). A ninth category combines other less-common species such as pickerel frog and mink frog (*Lithobates* spp.).

We used the arithmetic Index of Ecological Condition 2 (IEC2) to compare anuran (frog and toad) assemblages among Great Lakes coastal wetland sites. This metric uses occurrences of targeted wetland species (listed above) during standardized samples (described in Uzarski et al. 2017). Scores for species or species groups at a given site during a given year are determined by the occurrence (value = 1) or absence (value = 0) during any of 3 counts. In other words, the value for a given taxon is 0 only if the species was absent during all 3 seasonal samples.

The IEC2 metric replaces the likelihood metric (Index of Ecological Condition; Howe et al. 2007a, 2007b, Gnass Giese et al. 2015, Jung et al. 2020, and Howe et al. 2021) used during early years of the Great Lakes Coastal Wetland Monitoring Program. When the number of species is relatively small, IEC estimates are often unstable and may provide misleading results if just one or a few key species are present at a site. Frogs and toads are often impossible to count during evening auditory surveys, so analyses are limited to presence/absence data or highly subjective estimates of abundance; the IEC metric can be estimated with presence/absence data, but it tends to be more effective when abundance data are used. Finally, all anuran species regularly found in Great Lakes coastal wetlands are native, and all are at least somewhat sensitive to habitat degradation. Some species clearly are more vulnerable than others, but presence of any anuran species generally reflects positively on the quality of a wetland.

The new metric is highly correlated with species richness (Figure 22), but it "weights" species according to 1) their sensitivity to wetland disturbance and 2) their likelihood of occurrence and detection in highest quality wetlands. Species weights are derived from parameters of a BIOTIC RESPONSE (BR) FUNCTION representing each of the targeted anuran species, like the approach underlying the Index of Ecological Condition (Howe et al. 2007a, 2007b, Gnass Giese et al. 2015). Our BR functions are based on a multivariate gradient representing wetland area and the "human footprint" impacts on the wetland Elliott (2018). Variables used to derive the "human footprint" include wetland size, developed land and roads within 2 km of the wetland's center, agricultural land within 2 km, developed/agricultural land in the watershed flowing into the wetland, and human population within the watershed. Note: BR functions resemble the pre-determined COEFFIENTS OF CONSERVATISM often used for plant species indicator metrics (Bourdaghs et al. 2006), although the BR functions represent an empirically-derived, quantitative functional response rather than a subjective number assigned by experts.

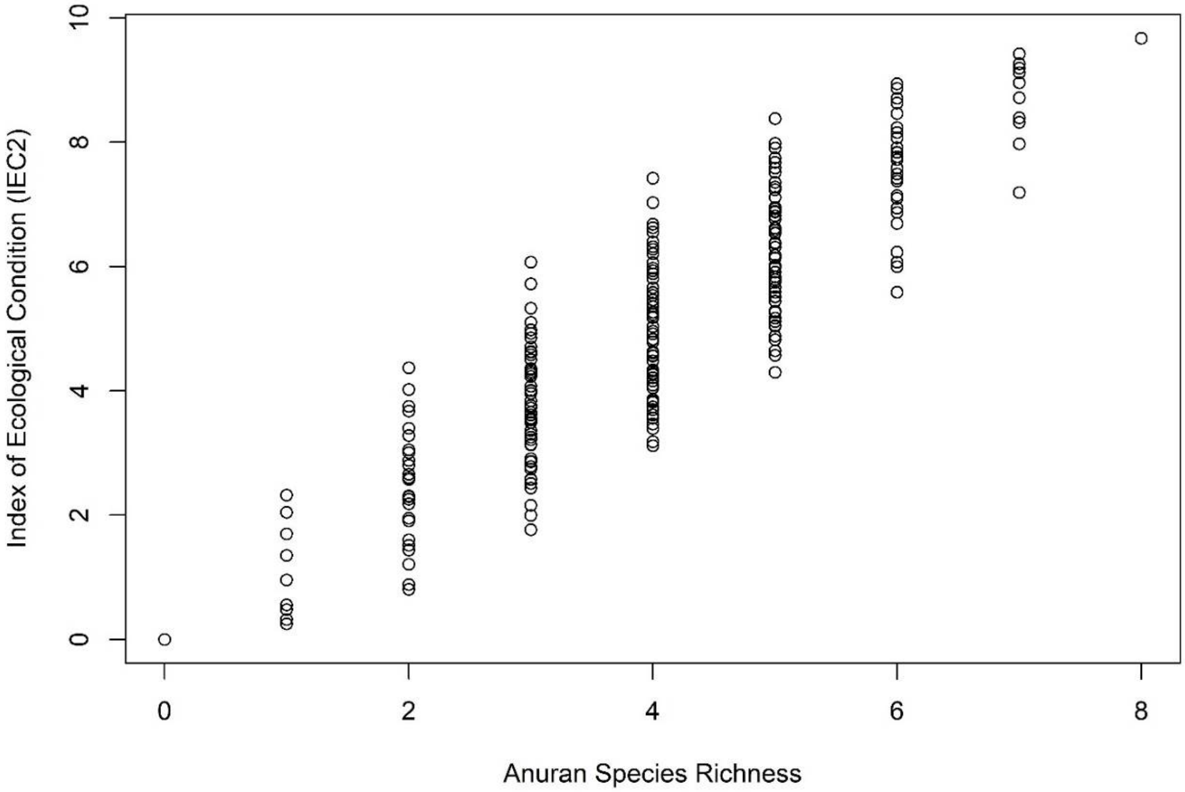

Figure 22. Relationship between species richness (number of anuran species/taxa) and the Index of Ecological Condition 2 (IEC2). Points (open circles) represent wetland points (n = 3299) sampled between 2015-2022. Note that for a given number of anuran species (e.g. 4), a point may have different values of IEC2 depending on the composition of species/taxa; points with a high IEC2 were characterized by species/taxa with higher weights (i.e., higher "quality" species).

Weights for each species are calculated as the product of two parameters: 1) the mean of the BR function and 2) the value of the BR function when the reference (environmental) gradient = 10. The BR function mean reflects the sensitivity of the species to the reference gradient; the more sensitive the species, the larger will be the mean. We limited the range of weights from 0 (least sensitive) to 10 (most sensitive), although the shape of BR functions might reflect normal distribution functions whose means extend beyond these limits (Gnass Giese et al. 2015). The second parameter reflects the probability of encountering the species at highest quality sites, influenced by the ubiquity (commonness) of the species and the probability of detecting individuals when the species is present. The value of IEC2 is the sum of weights for all species present at the wetland during the three seasonal counts, scaled from 0 (when no species are present) to 10 (when all species are present).

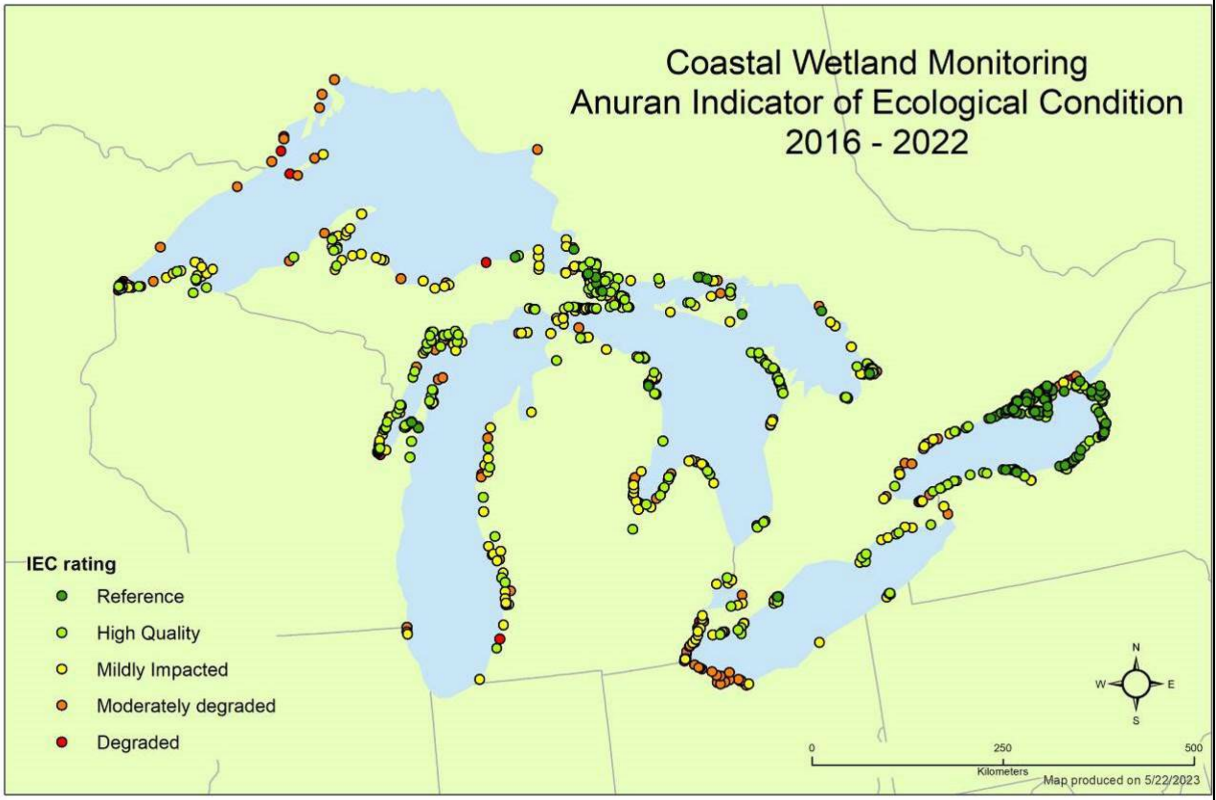

Figure 23. Condition of coastal wetland calling anuran communities. This indicator is based on the IEC method (see text) using data collected primarily between 2016 and 2022, with data from 2011-2015 used to create the the baseline for the indicator but only used to calculate the actual wetland

Finally, we have developed a water quality and land use 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 24).

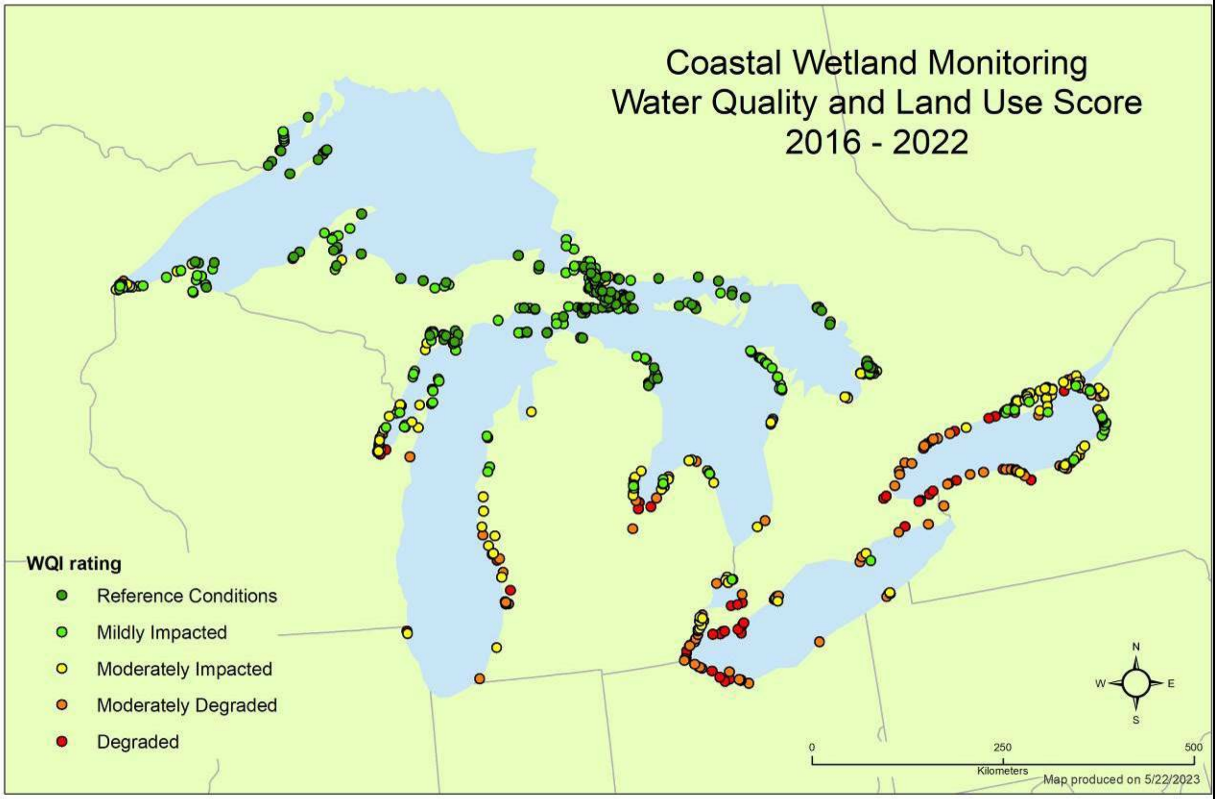

Figure 24. Disturbance gradient (SumRank) indicator. This indicator is based on landscape stressor data, site-based stressor data, and site water quality data. This is based on data collected from 2016 through 2022.

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 25). 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 25. 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 26):

- 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 26), or 2) year sampled (Figure 27); 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).

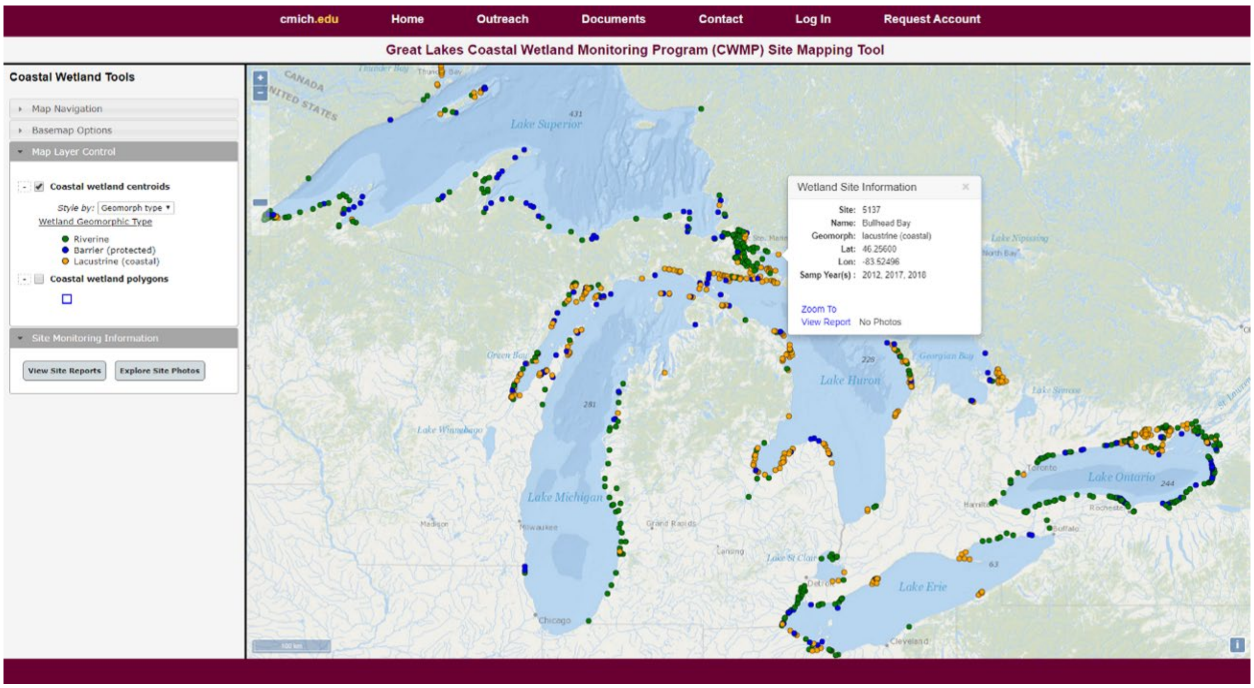

Figure 26. Coastal Wetland Mapping Tool – Public Version (geomorphic type view).

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.”

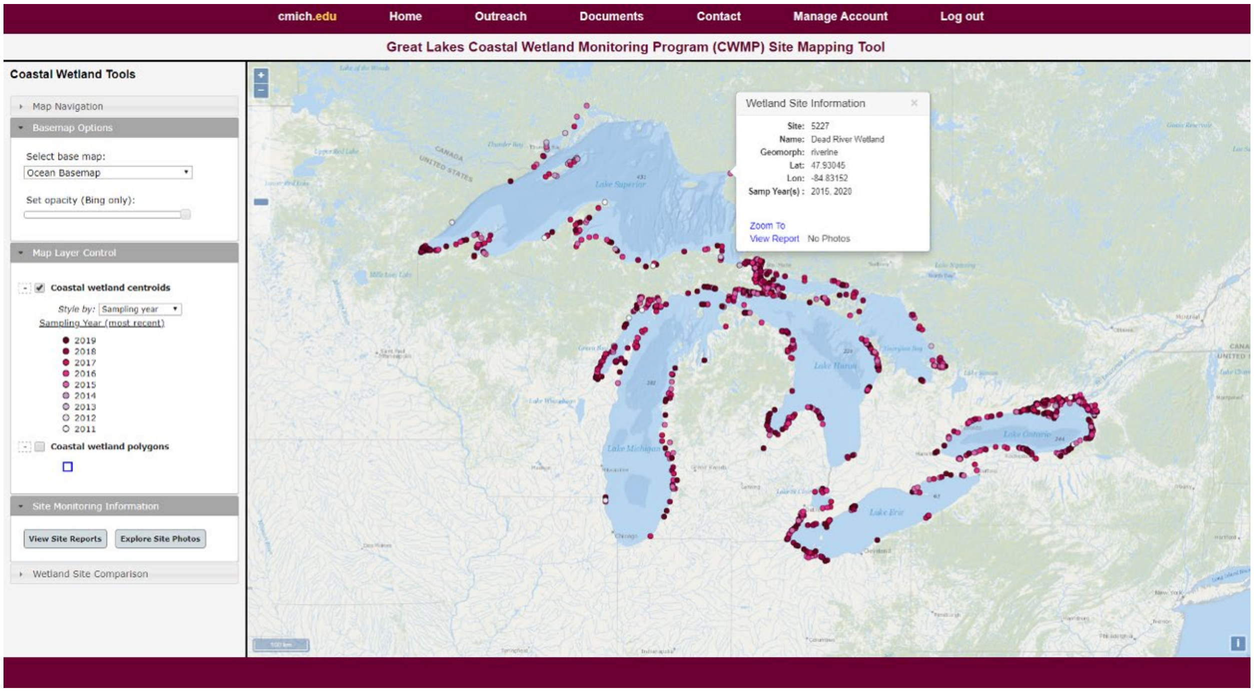

Figure 12. Coastal Wetland Mapping Tool – Public Version (sampling year view).

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

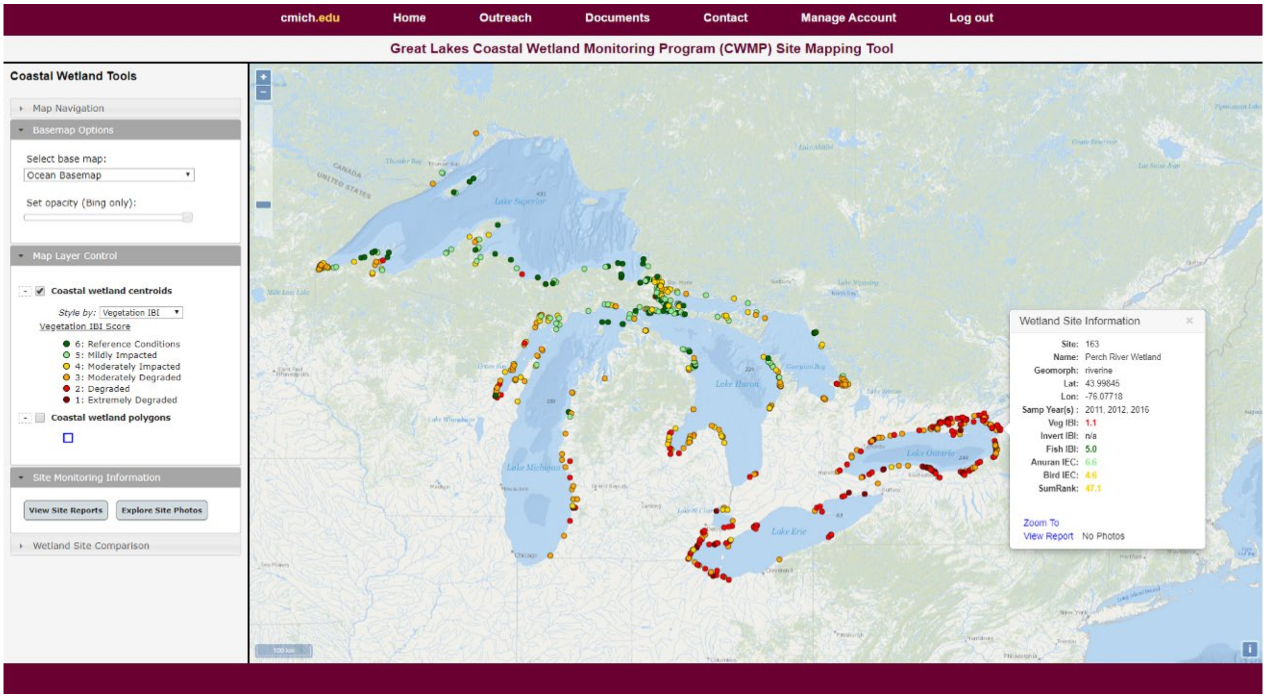

Figure 28. Coastal Wetland Mapping Tool with IBI scores displayed.

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 29), 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.

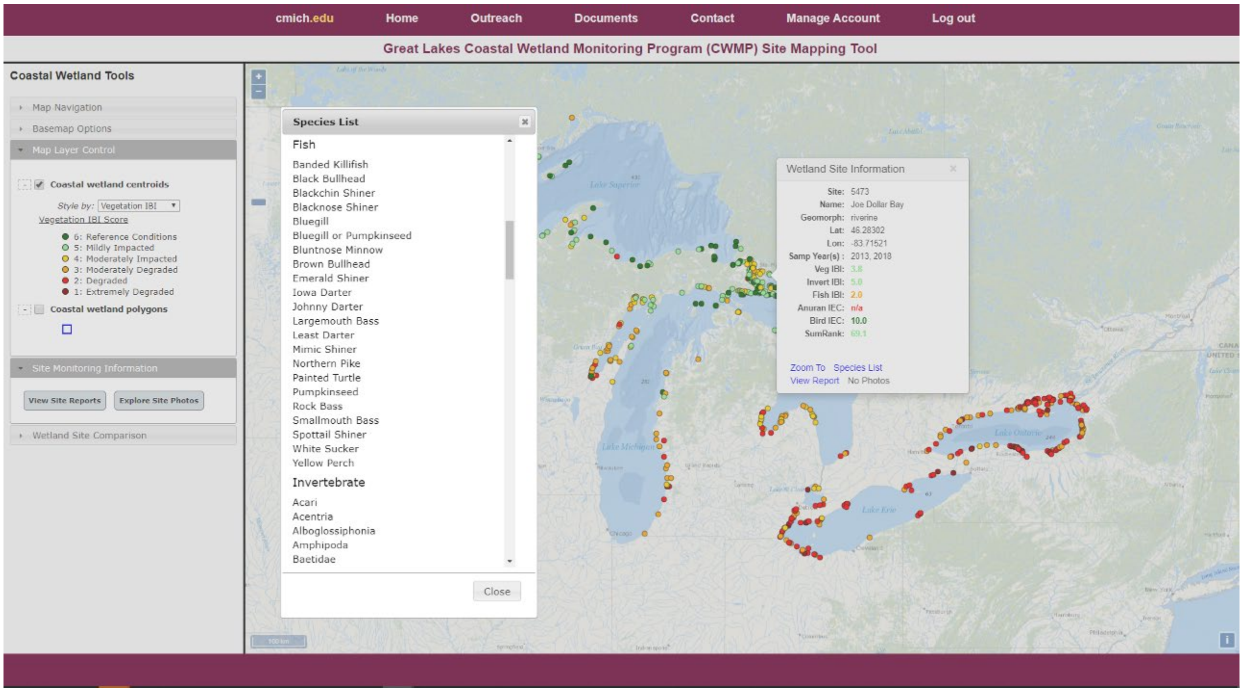

Figure 29. Coastal Wetland Mapping Tool with wetland macrophyte IBI scores and species list displayed.

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 seminar/training session in fall 2023 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 meeting 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 & ANURAN TEAM AT THE NATURAL RESOURCES RESEARCH INSTITUTE, UNIVERSITY OF MINNESOTA DULUTH

Team Members

- Dr. Annie Bracey, co-PI, avian ecologist (since 2012 as crew lead; 2 years since 2020 as co-PI)
- Josh Bednar, crew leader, wildlife ecologist (10 years since 2012)
- Jessie Green, summer field technician (this will be her first year on the project)
- Hannah Leabhart, summer field technician (this will be her first year on the project)

Training

Annual training for anuran surveys will be virtual on April 3, 2023 and the bird survey training will be held at the Natural Resources Research Institute May 22-26, 2023. 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

Nothing to report.

Site Visit List

In 2023, 35 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 35 sites, 25 will be surveyed for anurans and birds. Sites that were excluded were for the following reasons; could not access site (*n* = 7) which included remote sites on islands 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. Assuming travel restrictions to Canada are not reinstated, 9 of the 25 wetland sites will be surveyed by our team in Canada. One site is a resamples from 2022 and two sites we will survey are non-panel sites (i.e. benchmark sites) occurring in the St. Louis River Estuary. 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 2023 by the bird and anuran western team stretch from the Duluth-Superior harbor area and extend eastward along the south shore of Lake Superior as far as northeastern Lake Huron and Manitoulin Island.

Panel Survey Results (from fall report)

The data collected in 2022 by the western basin bird and anuran team were entered and error checked into the online data entry system and completed September 23, 2022.

Anurans: In 2022, a total of seven species of anurans were recorded throughout our study sites, with 843 individuals and 56 full choruses counted (Table 17). The average number of species detected per wetland was four, with a minimum of one and a maximum of six. There were four sites with six species recorded, site 980: Sturgeon River-Snake River Delta, a riverine wetland located south of Houghton, MI; site 1039: Fish Creek #1, a riverine wetland located in Ashland, WI; site 5106: Blind River 1, a riverine wetland located near Blind River, Ontario; and site 5210: Cranberry Creek, a barrier protected wetland located NW of Sault Ste. Marie, Ontario.

Spring peepers were the most abundant species detected in all wetlands sampled, accounting for 34% of the anuran observations and the majority of full chorus observations (Table 17). There were also large numbers of Green frog and Gray treefrog detections (Table 17). There was only one detection of Chorus Frog and no Mink Frog detections in 2022. The extended cold temperatures and extended ice-out period in the Lake Superior Basin in April and May could have delayed or reduced detections of Chorus Frogs. There were also fewer benchmark sites surveyed in Lake Superior in 2022 in locations where we typically detect Mink Frogs.

Table 17. List of anurans recorded during 2022 surveys. The number of individuals counted and the number of full choruses observed (i.e., number of individuals cannot be estimated) are provided for each species.

Species	Number of Individuals	Number of Observations (Full Chorus)
American toad (*Anaxyrus americanus*)	31	2
Blanchard's cricket frog (*Acris blanchardi*)	0	0
Bullfrog (*Lithobates catesbeianus)*	0	0
Chorus frog (western/ boreal – *Pseudoacris triseriata & P.maculatas*)	1	0
Green frog (*Lithobates clamitans*)	216	3
Gray treefrog (*Hyla versicolor*)	202	11
Mink frog (*Lithobates septentrionalis*)	0	0
Northern leopard frog (*Lithobates pipiens*)	82	2
Spring peeper (*Pseudoacris crucifer*)	286	38
Wood frog (*Lithobates sylvatica*)	25	0
Total	**843**	**56**

Birds: Birds were surveyed twice at each site between 03 June and 06 July. Surveys occurred once in the morning and once in the evening. A total of 96 identifiable species observations and 2,555 individual birds were recorded. The five most abundant species observed accounted for approximately 57% of all observations. These species, in order of decreasing abundance, were

Ring-billed Gull, Red-winged Blackbird, Common Yellowthroat, Tree Swallow, and Song Sparrow.

Interesting bird observations: In the Western Great Lakes region there have been many observations of birds of special concern in the vicinity of the wetlands or using the wetland complexes in 2022 (Table 18). Birds of special concern were observed in 15 of the 21 wetland sites surveyed in 2022. The most noteworthy observations included secretive marsh birds such as American Bittern, Least Bittern, Virginia Rail, Pied-billed Grebe, and Sora Rail. There were relatively low numbers of detections for both Virginia and Sora rails which seem to be lower in recent years.

Table 18. List of birds of special interest recorded during 2022 surveys. The number of individuals observed is listed for each species.

Species	Number of Individuals
Sandhill Crane (*Grus canadensis*)	15
Wilson's Snipe (*Gallinago delicata*)	3
Pied-billed Grebe (*Podiymbus podiceps*)	3
American Bittern (*Botaurus lentiginosus*)	5
Least Bittern (*Ixobrychus exilis*)	2
Virginia Rail (*Rallus limicola*)	3
Bald Eagle (*Haliaeetus leucocephalus*)	3
Common Loon (*Gavia immer*)	2
Sora Rail (*Porzana carolina*)	2
Great Blue Heron (*Ardea herodias*)	14
Green Heron (*Butorides virescens*)	1
Belted Kingfisher (*Megaceryle alcyon*)	5

Extra Sites and Data (from fall report)

Allouez Bay: Additional point-count locations were established in Allouez Bay (site 1077) in Superior, WI in 2020. Details for why additional data were collected at this site are provided in the 'Additional Funding and Projects' section. An additional six point-count locations were surveyed via boat to better survey sites within the wetland complex. We also deployed Automated Recording Units (ARUs) to supplement data collected by the 10-min in-person surveys. These data were externally funded and were not entered into the data management system. They are being stored digitally at NRRI.

Port Wing: We also collected bird and anuran data at a 'newly restored' location in site 1070 in Port Wing, Wisconsin per the request of the Wisconsin Department of Natural Resources. These data will be provided to WI DNR by Dr. Valerie Brady. Original datasheets and electronically scanned datasheets are being stored at NRRI.

Pickle Pond and Loon's Foot Landing: We conducted one round of bird surveys at Pickle Pond (1194), which is designated a benchmark site in the St. Louis River in Duluth-Superior harbor, for the EPA as part of their Great Lakes AOC Avian Indicators Project. We were initially scheduled to survey this site for birds as part of the CWMP 2022 sampling effort. However, the EPA placed their survey locations at slightly different locations from our previously established point count locations to align with placement of their digital audio recording units. Therefore, the EPA scientists conducted the first round of surveys at this site in 2022 and we conducted the second round of surveys at their designated survey (point count) locations. We also conducted a second round of sampling at Loon's Foot landing which is being used as the reference location. Therefore, we did not enter this data into the CWMP database and instead provided a digital copy of the surveys conducted by our team at the EPA designated survey locations in 2022 to the Great Lakes AOC Avian Indicator project team.

Wetland Condition Observations and Results

Condition of sites in the western basin in 2022 based on bird and anuran data did not differ substantially from previous years.

Data Processing

All data entry and QA for bird and anuran records was completed (100%) by September 2022. All new and returning field observers will review the current QAPP and SOPs and any new observers will complete the online certification requirements (see above) prior to conducting field surveys. The supervising PI will conduct mid-season checks by visiting survey locations and verifying that proper protocol is being implemented.

Audit and QC Report and Findings

The bird and anuran team are working through addressing all of GDIT's questions as they relate to data checks. Through this process, we have 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 2022 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 should begin in the spring of 2023.

This project is now moving into Phase 2, which is on-the-ground 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 (from fall report)

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

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

These data were then used in a spin-off project with Minnesota Land Trust, where bird communities were associated with spatially-explicit environmental and habitat variables to help guide conservation and management effort in the SLRE. In this project, we were also able to identify habitat availability at the landscape-level to identify specific features that are under-represented in the SLRE but likely important to avian species (specifically wetland-dependent species). These analyses have been used to guide restoration plans at specific locations within the SLRE, including Grassy Point (a wetland located in a heavily industrialized area of the SLRE). Efforts to restore this wetland site were developed using the habitat requirements of wetland-dependent marsh bird species as a guide and restoration goal. The plans for Grassy Point are complete and on-the-ground restoration begin in the Spring of 2020 and was completed in Fall of 2021.

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

The Grassy Point restoration plans, guided by avian breeding and stopover habitat needs, are currently in progress. Physical creation of an island and restoration of a degraded plant community within the adjacent wetland have been completed. A component of the post-restoration monitoring will include surveys of both breeding and migratory bird use.

We have been meeting with EPA scientists involved in the Great Lakes AOC Avian Indicators Project to discuss survey techniques associated with avian point counts and digital audio recording units. They are using a modified version of the CWMP sampling protocols to conduct bird surveys at AOC sites in the Great Lakes. We will continue to communicate with them and provide input about survey design and indicator metrics related to surveying birds as requested.

Other Data Requests

None.

Related Student Research

Lisa Elliot, a former graduate student used data from this program to conduct her PhD research. 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) was recently accepted in the journal *Ecosphere* and will be published and available later this spring. The title of the paper is '*Application of habitat association models across regions: useful explanatory power retained in wetland bird case study*'.

Figure 30. Site 1041, Sioux River Wetland, northern Wisconsin.

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

Team Members

- Dr. Valerie Brady, PI, aquatic invertebrate and wetland ecologist (12 years, since 2011)
- Dr. Chris Filstrup, co-PI, limnologist (4 years since 2019)
- Kristi Nixon, GIS specialist (7 years since 2016)
- Josh Dumke, team leader, fisheries ecologist (12 years, since 2011)
- Kari Hansen, crew leader, fish, invertebrate, and water quality sampling (9 years, since 2014)
- Bob Hell, aquatic invertebrate and fish taxonomist (12 years, since 2011)
- Holly Wellard Kelly, aquatic invertebrate and algal taxonomist (8 years, since 2015)
- Two part-time computer programmers (1 @ 7 yrs, 1 @ 2 yrs)
- Five summer field techs, 2 returning and three new summer 2023

Training

The NRRI fish/invert/wq team will hold in-person safety and classroom project training in early June, 2023, as well as hands-on training for new summer technicians during their first site visit in Green Bay, WI (mid-June, 2023). The entire NRRI team (typically 9-10 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 multi-parameter instruments, invertebrate collection and field picking of samples, vegetation identification and habitat quadrats. Hands-on field sampling and safety training will be led by experienced crew leaders Kari Hansen, Bob Hell, and Holly Wellard-Kelly who have all worked on GLCWMP for more than 5 years. During hands-on training the experienced NRRI crew leaders (n=3) will guide new summer technicians (n=3) and returning summer technicians (n=2) 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 (from summer 2022)

The 2022 field season saw nearly a complete return to pre-pandemic operations. However, all members of our field team contracted COVID-19 at different times throughout the summer. Everyone was vaccinated and boosted so symptoms were relatively mild, but it did regularly disrupt our planned travel and daily operations. We minimized interruption in our work schedule by having 'backup' members of our field team on standby to substitute for ill/quarantined workers whenever someone caught or was exposed to COVID-19. Completing the assigned work while mitigating interruptions caused by COVID-19 was a substantial challenge the NRRI team had to overcome in 2022, and we will likely need to prepare for similar difficulties in 2023.

Every year all GLCWMP field teams deal with the challenges of inclement weather, but in 2022 the NRRI field team had to deal with the aftermath of a tornado in Green Bay, WI. The team worked at site 1441 all day from inflatable Zodiak boats. All fyke nets were deployed and they were nearly done for the day when another team member informed them via text that a bad storm was approaching and they needed to leave within the hour. The team chained the Zodiaks to a tree and left right as heavy rain fell. The crew was staying in UW-Green Bay dorms, and an hour after arriving there everyone's cell phones alerted them to a tornado warning. Sirens were blaring in the city. The UW-Green Bay resident assistant went door-to-door gathering all occupants and brought everyone to the first floor to wait out the tornado warning. The night passed without incident at the dorms, but when the crew tried to access the site the next day they found that the road was blocked by dozens of downed trees and branches. Most debris were small enough to move by hand, and the larger trees were cut with hand saws borrowed from neighboring residents (who have always been very helpful to crews working at this site). The crew found that the nets and Zodiaks left at the site were still in place, and the nets even caught fish!

Site Visit List

The 2023 CWMP field season for the NRRI team consists of 24 sites. Of these 24 sites, there are 18 regular sites, 3 resample sites, and 3 benchmark sites. The sites are located in Michigan counties Alger (1), Delta (2), and Menominee (1); Wisconsin counties Ashland (3), Bayfield (4), Douglas (1), Door (1), Brown (3), Oconto (3); and Minnesota St. Louis County (5). Three of our 2023 sites are located in the Apostle Islands in Ashland County, WI. One site, 1063, will require permission and coordination from the Red Cliff Band of Lake Superior Chippewa to access. Pre-

COVID we always received permission from the Band to sample 1063, but access into the reservation by non-essential and non-tribal members was restricted in recent years to limit risk of COVID-19 being introduced to the Band. We will be contacting the Red Cliff Band requesting permission to sample 1063 soon.

Site 7073 was created as a new benchmark in 2019 in an area of the St. Louis River Estuary (Duluth, MN) scheduled for restoration. Pre-restoration sampling was conducted that same year. In 2023 we will return to conduct post-restoration sampling.

Site 7074 was created as a new benchmark in 2019 in an area of the St. Louis River Estuary (Duluth, MN) scheduled for restoration. Pre-restoration sampling was conducted in 2019, but restoration work had already begun, despite not being scheduled (we were told) until 2020. Crews sampled as best as they could in remaining un-restored areas of the site. In 2023 we will conduct post-restoration sampling.

Site 7078 was created as a new benchmark at the request of Wisconsin Department of Natural Resources (WDNR). The site is located in Green Bay, WI and is surrounded by industry. WDNR intend to start restoration work soon and would like our team to collect pre-restoration data following CWM methods on water quality, habitat, and all taxa except fish.

Panel Survey Results (from summer 2022)

<u>Regular Panel Sites:</u>

942 – First sampled on 8-8-2012 by the Notre Dame team. Last visited by NRRI on 7-25-2022 and sampled an Outer Schoenoplectus zone for fish, invertebrates, and water quality, as well as a Lily zone for invertebrates and water quality. Nets at this site (n=3) captured Rock Bass, Brown Bullhead, Yellow Perch, Blacknose Shiner, Smallmouth Bass, and Spottail Shiner. No invasive fish were detected. There were no crayfish or turtle bycatch in nets at this site.

951 – First sampled on 8-7-2012 by the Notre Dame team. Last visited by NRRI on 7-24-2022 and sampled an Outer Schoenoplectus zone for fish, invertebrates, and water quality, as well as a Lily zone for invertebrates and water quality. Nets at this site (n=3) captured Rock Bass, Brown Bullhead, Blacknose Shiner, Smallmouth Bass, and Spottail Shiner, Three-spine Stickleback, Bluntnose Minnow, Pumpkinseed Sunfish, Green Sunfish, White Sucker, Logperch, Johnny Darter, and Common Shiner. No invasive fish were detected. There were no crayfish bycatch, but there were 3 painted turtles.

973 – First sampled on 7-31-2012 by the LSSU team. Last visited by NRRI on 7-17-2022 and sampled a Sparganium zone for invertebrates and water quality. Crew leader Holly Wellard-Kelly noted that while the site polygon is large, relatively little area of the site is actually inundated with water sufficient for fish/invert/wq sample criteria. Fish were not sampled at this site.

980 – First sampled on 8-1-2012 by the LSSU team. Last visited by NRRI on 7-22-2022 and sampled Peltandra/Pontedaria, Typha, and Outer Schoenoplectus zones for fish, invertebrates, and water quality, as well as a Lily zone for invertebrates and water quality. Nets at this site (n=9) captured Brown Bullhead, Black Crappie, Golden Shiner, Largemouth Bass, Northern Pike, Yellow Perch, Pumpkinseed Sunfish, Bluegill Sunfish, Smallmouth Bass, Emerald Shiner, and Rock Bass. No invasive fish were detected. There were 2 native crayfish and 20 painted turtles as bycatch in fyke nets.

989 – First sampled on 8-4-2012 by the NRRI team. Last visited by NRRI on 7-23-2022 and sampled Outer Schoenoplectus and SAV zones for fish, invertebrates, and water quality, as well as a Lily zone for invertebrates and water quality. Nets at this site (n=6) captured Bluegill Sunfish, Pumpkinseed Sunfish, Yellow Perch, Brown Bullhead, Rock Bass, Spottail Shiner, Golden Shiner, Blacknose Shiner, White Sucker, Shorthead Redhorse, and Trout Perch. No invasive fish were detected. There were 1 native crayfish, 11 painted turtles, and 3 common snapping turtles as bycatch in fyke nets.

999 – First sampled on 8-6-2012 by the NRRI team. Last visited by NRRI on 7-18-2022 and sampled Outer Schoenoplectus and Lily zones for fish, invertebrates, and water quality, as well as a Wet Meadow zone for invertebrates and water quality. Nets at this site (n=6) captured Rock Bass, Smallmouth Bass, Bluntnose Minnow, Yellow perch, Pumpkinseed Sunfish, and Northern Pike. No invasive fish were detected. There was no crayfish bycatch, but there were 3 painted turtles.

Figure 31. Image taken by NRRI field crew leader Holly Wellard-Kelly at site 999. A carnivorous sundew plant (*Drosera spp*.) had captured a dragonfly that made the mistake of landing on the sundew's sticky tendrils.

1027 – First sampled on 8-7-2012 by the NRRI team. Last visited by NRRI on 7-15-2022 and sampled a Tyhpa zone for fish, invertebrates, and water quality, as well as an SAV zone for invertebrates and water quality. Nets at this site (n=3) captured Golden Shiner, Pumpkinseed Sunfish, Rock Bass, Hornyhead Chub, Black Bullhead, Common Shiner, Northern Pike, Blacknose Shiner, Creek Chub, and Spottail Shiner. No invasive fish were detected. There were 4 native crayfish and 5 painted turtles as bycatch in fyke nets.

1028 – First sampled on 8-8-2012 by the NRRI team. Last visited by NRRI on 7-17-2022 and sampled an SAV zone for fish, invertebrates, and water quality. Field crew chief Holly Wellard-Kelly noted that this site unpredictably becomes closed off from Lake Superior surface water contact by a sandbar. Due to uncertainty in accessing the site with a large workboat from Lake Superior, the team acquired landowner permission and accessed the site with inflatable Zodiaks from private property. Nets at this site (n=3) captured Logperch, Spottail Shiner, Common Shiner, Golden Shiner, Pumpkinseed Sunfish, Rock Bass, Black Bullhead, Blacknose Shiner, and

Johnny Darter. No invasive fish were detected. There were 12 native crayfish and 10 painted turtles as bycatch in fyke nets.

1039 – First sampled on 7-25-2011 by the NRRI team. Last visited by NRRI on 8-3-2022 and sampled Peltandra/Pontedaria, Typha, and Outer Schoenoplectus zones for fish, invertebrates, and water quality. This site will be a temporal re-sample site in 2023. This site was very large and split into East and West wetlands, so two teams worked at this site over two days to adequately cover the site area. Nets at this site (n=9) captured Pumpkinseed Sunfish, Yellow Perch, Bluegill Sunfish, Black Bullhead, Green Sunfish, Brown Bullhead, Northern Pike, Tadpole Madtom, Common Carp, Rock Bass, Central Mudminnow, Yellow Bullhead, Golden Shiner, Spottail Shiner, Emerald Shiner, Bluntnose Minnow, White Sucker, Ruffe, and Johnny Darter. Invasive fish captured were Common Carp young-of-year (n=2) and Ruffe (n=4), so at least the abundances of invasive fish were low. Green Sunfish (figure 32) are native to the Great Lakes, but this is the first time in 11 years of the CWMP where NRRI has detected a Green Sunfish in a Lake Superior wetland, so they are clearly uncommon in the Western Lake Superior region. Also, there were 3 native crayfish and 5 painted turtles as bycatch in fyke nets.

Figure 32. A Green Sunfish (*Lepomis cyanellus*) captured from a Peltandra/Pontedaria vegetation zone at site 1039. This is the first Green Sunfish to be captured in this region since the beginning of GLCWMP.

1076 – First sampled on 9/20/2011 by the NRRI team. Last visited by NRRI on 8/9/2022 and sampled an SAV zone for fish, invertebrates, and water quality. Crew chief Bob Hell noted that a sandbar prevented direct connection to Lake Superior at the time of their visit, but the wetland is typically connected by the flowing Poplar River. Nets at this site (n=3) captured Northern

Pike, Golden Shiner, Black Bullhead, Black Crappie, Pumpkinseed Sunfish, Logperch, Brown Bullhead, Common Carp, Spottail Shiner, Tadpole Madtom, Rock Bass, and Blacknose Shiner. Invasive fish captured were Common Carp young-of-year (n=5). There was 1 common snapping turtle as bycatch in fyke nets.

1391 – First sampled on 6/24/2017 by the NRRI team. Last visited by NRRI on 6/18/2022 and sampled an SAV zone for invertebrates, and water quality. Water levels were too low to sample fish. The field team accessed the site by hiking in from land.

1441 (re-sample) – First sampled on 7/1/2014 by the NRRI team. Last visited by NRRI on 6/15/2022 and sampled an SAV zone for fish, invertebrates, and water quality, as well as a Typha zone for invertebrates and water quality. Nets at this site (n=3) captured Yellow Perch, Golden Shiner, Black Bullhead, Fathead Minnow, Emerald Shiner, White Sucker, Brook Stickleback, Bowfin, Central Mudminnow, Green Sunfish, Threespine Stickleback, Fathead Minnow, Longnose x Shortnose Gar hybrid, Northern Pike, and Brown Bullhead. This site is managed by the University of Wisconsin Green Bay. Over the many years of sampling this wetland (this year was the 6th time NRRI has sampled site 1441) we have found the local landowners to be very accepting and helpful toward our field teams.

1446 – This site has not been sampled for GLCWM before. The site was visited for the first time by NRRI fish/invert/wq team on 6/16/2022 and sampled SAV and Typha zones for fish, invertebrates, and water quality. This site will be sampled in 2023 as a temporal re-sample site. Field crew chief Kari Pierce noted wild rice was present at the site, so prior wild rice seeding starting in 2017 has started to establish. Nets at this site (n=6) captured Longnose x Shortnose Gar hybrid, Bowfin, Round Goby, Emerald Shiner, Pumpkinseed Sunfish, Banded Killifish, Yellow Perch, White Sucker, White Perch, Spottail Shiner, Common Carp, Golden Shiner, Bluegill Sunfish, Black Crappie, Rock Bass, Largemouth Bass, Freshwater Drum, Brown Bullhead, Yellow Bullhead, and Channel Catfish. There were so many adult Longnose x Shortnose Gar hybrids caught in the Typha zone (n=261) that it took all six crew members to lift these three nets into the boat. Invasive fish captured were Round Goby (n=5) and Common Carp (n=2; Figure 33), and there were 2 painted turtles as bycatch in fyke nets.

Figure 33. A unique catch at site 1446 was a 'Mirror Carp' (*Cyprinus carpio*), which is still a Common Carp, but possesses a mutation that produces irregular patches of scales.

1456 (re-sample) – First sampled on 6/22/2021 by the NRRI team. Last visited by NRRI on 6/18/2022 and sampled SAV and Typha zones for fish, invertebrates, and water quality. Nets at this site (n=6) captured Bowfin, Longnose x Shortnose Gar hybrid, Yellow Perch, Emerald Shiner, White Perch, Pumpkinseed Sunfish, Banded Killifish, Brown Bullhead, Round Goby, Common Carp, and Channel Catfish. This site is an important spawning and rearing area for Yellow Perch, as the field team counted about 10,000 young-of-year Yellow Perch at this site. Invasive fish captured were Round Goby (n=3) and Common Carp (n=2)

1457 – First sampled on 7/6/2012 by the NRRI team. Last visited by NRRI on 6/18/2022 and sampled an SAV zone for fish, invertebrates, and water quality. Nets at this site (n=3) captured Alewife, Yellow Perch, Emerald Shiner, White Perch, Spottail Shiner, Fathead Minnow, Bowfin, and Round Goby. Invasive fish captured were Alewife (n=6) and Round Goby (n=1).

1467 – First sampled on 7/13/2012 by the NRRI team. Last visited by NRRI on 7/29/2022 and sampled SAV, Phragmites, and Outer Schoenoplectus zones for fish, invertebrates, and water quality. This site will be sampled again in 2023 as a temporal re-sample site. Nets at this site (n=9) captured Gizzard Shad, Common Shiner, Yellow Perch, White Perch, Spottail Shiner, Banded Killifish, Alewife, Round Goby, Tadpole Madtom, Logperch, Emerald Shiner, Golden Shiner, Longnose x Shortnose Gar hybrid, Bowfin, Brown Bullhead, and White Sucker. Invasive fish captured were Alewife (n=266) and Round Goby (n=28). There were 3 painted turtles as bycatch in fyke nets.

1494 – First sampled on 7/18/2012 by the NRRI team. Last visited by NRRI on 7/10/2022 and sampled Typha and Outer Schoenoplectus zones for fish, invertebrates, and water quality. Crew chief Kari Pierce noted that wild rice seeding was done at this site, and wild rice plants were visible. Nets at this site (n=6) captured Brown Bullhead, Pumpkinseed Sunfish, Rock Bass, Largemouth Bass, Smallmouth Bass, Yellow Perch, Black Crappie, Johnny Darter, Longnose Gar, and Bowfin. No invasive fish were detected. There were 12 painted turtles, 2 common snapping turtles, and 3 native crayfish as bycatch in fyke nets.

1514 – First sampled on 7/21/2012 by the NRRI team. Last visited by NRRI on 7/9/2022 and sampled a Typha zone for fish, invertebrates, and water quality. Nets at this site (n=3) captured Smallmouth Bass, Common Shiner, Bluntnose Minnow, Rock Bass, Pumpkinseed Sunfish, Spotfin Shiner, Round Goby, Yellow Perch, Bowfin, Golden Shiner, and Black Bullhead. Invasive fish captured were Round Goby (n=22), and there were 4 native crayfish as bycatch in fyke nets.

1687 – First sampled on 7/3/2012 by the NRRI team. Last visited by NRRI on 7/31/2022 and sampled a Lily zone for invertebrates and water quality. Lily was not sampled for fish because of deep water and soft bottom making it impossible to get out of the boat. SAV at the site was in water depths exceeding 1.5 m, and other vegetation types along the shoreline were too small or too well-mixed with other vegetation to be monodominant stands. Crew chief Josh Dumke noted the site was releasing methane or similar gas evident by bubbles and a strong ‘farm animal’ smell while working at the site.

1703 – First sampled on 7/14/2012 by the NRRI team. Last visited by NRRI on 7/11/2022 and sampled Typha and Outer Schoenoplectus zones for fish, invertebrates, and water quality. Nets at this site (n=6) captured Brown Bullhead, Rock Bass, White Perch, Pumpkinseed Sunfish, Bluegill Sunfish, Banded Killifish, Rock Bass, Largemouth Bass, Yellow Perch, Round Goby, Bowfin, Brown Bullhead, Emerald Shiner, Golden Shiner, White Sucker, Bluntnose Minnow, Smallmouth Bass, Spotfin Shiner, and Tadpole Madtom. Invasive fish captured were Round Goby (n=303). There were 4 painted turtles and 2 common snapping turtles as bycatch in fyke nets.

1747 – First sampled on 7/21/2012 by the NRRI team. Last visited by NRRI on 7/8/2022 and sampled an Outer Schoenoplectus zone for invertebrates and water quality, as the zone was too small to accommodate three fyke nets.

1754 – First sampled on 7/22/2012 by the NRRI team. Last visited by NRRI on 7/8/2022 and sampled an Outer Schoenoplectus zone for fish, invertebrates, and water quality. Nets at this site (n=3) captured Rock Bass, Smallmouth Bass, Common Shiner, Round Goby, Bluntnose Minnow, Brown Bullhead, Threespine Stickleback, and Yellow Perch. Invasive fish captured were Round Goby (n=142), and there were 7 painted turtles as bycatch in fyke nets.

Benchmark sites

1194 – First sampled on 8/18/2016 by the NRRI team. Last visted by NRRI on 8/11/2022 and sampled an SAV zone for fish, invertebrates, and water quality, as well as a Typha zone for invertebrates and water quality. The field crew accessed the site by launching inflatable Zodiak boats from shore. Sampling in 2022 was intended to capture 'pre-restoration' data in advance of planned habitat work to remove contaminated sediments and increase connectivity to St. Louis River Estuary, as requested by US EPA. Nets at this site (n=3) captured Silver Redhorse, Pumpkinseed Sunfish, Black Bullhead, Yellow Perch, Bluegill Sunfish, Rock Bass, Tadpole Madtom, Golden Shiner, Smallmouth Bass, Black Crappie, Tubenose Goby, Northern Pike, Common Shiner, Walleye, Threespine Stickleback, and Johnny Darter. Invasive fish captured were Tubenose Goby (n=7). Threespine Stickleback are non-native to Lake Superior, but are not managed as an invasive species since they don't cause measurable ecological or economic harm. There were 13 painted turtles as bycatch in fyke nets.

7077 – This site has not been sampled for GLCWM before. 7077 is an SLRIDT Superfund site which has been cleaned up and is being delisted. The benchmark special request comes from the AOC committee. The site was visited for the first time by NRRI fish/invert/wq team on 8/15/2022 and sampled an SAV zone for fish, invertebrates, and water quality, as well as a Typha zone for invertebrates and water quality. Crew chief Kari Pierce noted that the team only sampled the Western part of the site because the other areas of the site polygon had very little vegetation. Nets at the site (n=3) captured Black Crappie, Rock Bass, Largemouth Bass, Bluegill Sunfish, Pumpkinseed Sunfish, Golden Shiner, Brown Bullhead, Tadpole Madtom, Yellow Perch, Logperch, Tubenose Goby, and Ruffe. Invasive fish captured were Tubenose Goby (n=1) and Ruffe (n=1). There were 33 painted turtles and 1 common snapping turtle as bycatch in fyke nets.

Extra Sites and Data (from summer 2022)

1070 – First sampled on 7-24-2013 by the NRRI team. Last visited by NRRI on 8-8-2022 by special request from Wisconsin Department of Natural Resources. WDNR requested that we sample a very small portion of this site, which has had extensive restoration activities applie to it and is named for a beloved staff member who died in 2020. This restoration area could only be accessed by walking in because it was not possible to use an outboard motor in the dense vegetation and shallow water. At this site the team sampled SAV and Mixed Emergent zones for invertebrates and water quality. Fish were not sampled at this site. The NRRI field team noted that another crew was out at this part of the wetland cutting vegetation, so restoration activities are ongoing. Because the whole site was not sampled, these data are not being entered into the CWMP database and instead are being provided directly to WDNR.

Wetland Condition Observations and Results (from summer 2022)

Vegetation zones seemed to be in flux because of changing water levels (going from very high water to lower water for the past 2 years). Some vegetation zones were too deep to sample, while others were too shallow to sample with fyke nets. Field teams also often observed mixed vegetation stands, which made determinations about monodominant vegetation types fitting GLCWMP criteria difficult. It is possible we are observing vegetation zones “moving” as a response to changing lake levels.

Data Processing

As of April, 2023 the NRRI fish/invert/wq team has completed invertebrate ID from 147 samples collected in the 2022 field season. Field datasheets have all been digitized. All fish, habitat, and water quality data are entered into the database and quality control is complete. All that remains is about 10% of the invertebrate data entry and QC.

Mid-season QC Check Findings (from summer 2022)

Primary long-time crew leader Kari Hansen administered mid-season QC check of fish identification with new crew members. In 2022 the 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

QC exchange of invertebrate samples between team labs has not occurred yet, but is presently underway. The NRRI team usually swaps samples with LSSU, but the new LSSU taxonomist is still in training. NRRI is working on sending invertebrates to the U Windsor lab for QC. In addition, we have evaluated the data from 2016-2022 to check for errors as an additional quality control measure using a data verification interface. Fields in the database were flagged if data were missing, outside the designated range listed in the QAPP, or potentially a duplicate. This included all the fish data, zone data, water quality data, and invertebrate data. In the verification interface, flagged fields were then marked as resolved or not possible to resolve and given a data usability code. The data usability code options were either fully usable for all purposes, scientific research usage only, or not usable for any purpose. Using this data verification interface allowed us to fix any data entry errors that had been previously missed and to select data to not be used in analyses, if necessary. Some of the data, such as the fish data, returned thousands of error results. Most of these were flagged simply because of data entry errors and were easily resolved.

Additional Funding and Projects

None.

Other Collaboration Activities

PI Brady continues to collaborate with MPCA, MN DNR 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

The Door County Land Trust (WI) requested data generated by GLCWMP for site 1406: Detroit Harbor. The site is listed as a WI State Natural Area but it is owned and managed by the DCLT. All GLCWMP data acquired to date was shared with DCLT.

Related Student Research

PI Brady's graduate student, Adam Frankiewicz, continues his work on better ways to identify sphaeriid (fingernail) clams of the Great Lakes region to species. He has used CWMP samples to help with this effort and CWMP field crews have collected clams for him.

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

Team Members

- Nicholas Danz, PI, wetland plant ecologist (12 years since 2011)
- Kelly Beaster, co-crew leader, botanist (7 years since 2016)
- Read Schwarting, co-crew leader, botanist (7 years since 2016)
- Ryne Rutherford, co-crew leader, botanist (9 years since 2014)

Training (update)

All UWS team members have over 5 years of experience on the project and are qualified to train others. In all field work, teams of two individuals will be paired 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 2023, UW-S crew members will be present to participate.

Challenges and Lessons Learned

In the coming 2023 field season, we anticipate Lake Superior and Lake Michigan water levels to be about average, with heavy snowfalls and precipitation throughout the region that are likely to bring water levels higher than last year. We have encountered this type of fluctuation before and envision a somewhat normal field sampling season.

Site Visit List

The UWS vegetation team will visit 24 sites in 2023.

site	name	site	name
945	Au Train River Wetland	1446	Peats Lake Wetland #2
1039	Fish Creek Wetland #1	1464	Charles Pond Wetland
1043	La Pointe Wetland	1465	Pensaukee River Wetland
1049	Stockton Island Wetland	1467	Pensaukee River Area Wetland #2
1051	Presque Isle Point Wetland	1475	Cedar River Wetland #1
1063	Little Sand Bay Wetland	1489	Escanaba River Wetland
1070	Bibon Lake-Flag River Wetland	1516	Upper Big Bay De Noc Wetland
1074	Amnicon River Wetland	7048	BENCHMARK:40th Ave West
1090	Tallas Island Wetland	7050	Radio Tower Bay
1187	Sioux River Area Wetland	7073	Benchmark: Kingsbury Creek Wetland
1438	Henderson Point Wetland	7074	Benchmark: Grassy Point wetland
1444	Atkinson Marsh	7078	Benchmark: Tank Farm Marsh

Panel Survey Results

N/A

Extra Sites and Data

Site 7078 is a new site in the Green Bay area that is pre-restoration with restoration plans currently underway.

Wetland Condition Observations and Results

N/A

Data Processing

All vegetation data have been entered into the CWM database. QC checks were completed by Reed Schwarting, Ryne Rutherford, and Jenny Rutherford through Fall 2022.

Mid-season QC Check Findings

N/A

Audit and QC Report and Findings

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

In addition to CWM work in 2022, we plan to survey several hundred points (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. We will continue to collaborate with MCPA through the coming year and plan to use some historical CWM data to help with the efforts to develop indicators of vegetation quality.

Other Collaboration Activities

We have continued to rely on contractor botanist Ryne Rutherford to assist with our vegetation sampling at Green Bay and Upper Peninsula CWM sites. In 2022, Rutherford et al. produced a publication to document vegetation changes on a site in Lake Michigan and reported first observation of Frog-bit.

Rutherford, R., Hartsock, J.A., and Danz, N.P. 2022. Physical and plant community changes at a Lake Michigan coastal marsh related to a two-meter increase in lake level. Wetlands Ecology and Management 30(3):547-560.

Other Data Requests

N/A

Related Student Research

N/A

US CENTRAL BASIN BIRD & ANURAN TEAM AT THE COFRIN CENTER FOR BIODIVERSITY, UNIVERSITY OF WISCONSIN-GREEN BAY

Team Members

- Erin Giese, PI, bird/anuran ecologist (11 years since 2011)
- One full-time summer field crew leader (2 years since 2021)
- Three full-time summer field techs (1 year since 2022)
- One part-time summer field tech, new summer 2023

Figure 34. Summer student field technicians for summer 2022.

Training (from fall report)

Between February and June 2022, all trainings with summer field technicians were led by Erin Giese and conducted at UW-Green Bay either in person or online. One new anuran field technician and two new bird field technicians passed online tests of identification designed by the bird/anuran teams during the past decade. Our part-time summer field technician served as a project assistant and only conducted habitat surveys, not anuran or bird surveys.

February 3-May 27, 2022: Giese met weekly and separately with each bird field tech

Challenges and Lessons Learned (from fall report)

High lake water levels continued to create challenges in accessing points despite water levels starting to drop. Some points still have little or no emergent wetland vegetation within 100 m of historical sampling localities. We used boats to reach 17 bird-only points at 10 wetland sites (9 points by motor boat, 8 points by kayak).

This year, our team was also assigned a substantial number of sites located on inaccessible private property or sites that were impossible to access due to private roads, unimproved roads, or remote islands. Our crew also experienced serious challenges accessing site 1514 because it was highly water-logged. Two students became extremely stuck in water and mud to the point of almost needing additional assistance to get out (they were thankfully able to get out safely); therefore, our team dropped site 1514 this year. Our team also did not survey our historic three land-based, ground points at site 796 due to our crew stumbling on an active ground wasp nest in 2021; one of our crew members is allergic to bee/wasp stings; therefore, we instead accessed site 796 via motor boat.

Site Visit List

Fall Report

Our team was assigned 47 total wetland sites and we were successful at sampling 31 wetland sites. Of those 31 sites, 3 were "drowned" due to high water and thus assigned "could not sample" in the online site status database. However, we did still sample these "drowned" sites for the sake of historical continuity and future water level analyses. We were unable to survey 16 wetland sites largely due to sites being located along inaccessible private property or sites that were impossible to access due to private roads, unimproved roads, lack of roads, or remote islands. Of the 31 total sites we sampled, we surveyed 4 pre-sample ("P") sites, 5 re-sample ("R") sites (though site 915 was completely inundated with water), and 0 benchmark ("B") sites.

We surveyed 49 total point count locations, of which 23 were surveyed for birds only due to access issues for late night anuran surveys. Of the 49 points surveyed, 5 points were considered "drowned" due to high water. Nine remote or island points were accessible only by motorized boat, while 8 points were accessible by kayaks or canoes.

Update

Our team was assigned 44 total wetland sites: 12 in Wisconsin and 32 in Michigan, though we will undoubtedly drop several sites that are not accessible (e.g., distant, remote islands; lack of roads). Of our 44 assigned sites, there are 3 pre-sample ("P") sites, 3 re-sample ("R") sites, and 2 benchmark ("B") sites. Benchmark site 1598, which is located close to the line 5 oil pipeline in the Mackinac Straits, was requested as a benchmark to gather historical data in the event of an oil spill. The WI Department of Natural Resources requested sampling be conducted at newly created site 7078 since they are planning wetland restoration here and seek pre-restoration data to inform design plans.

Panel Survey Results (from fall report)

Our first surveys of the 2022 season took place on April 21, 2022 at sites 1441, 1446, and 1687 in Green Bay and Sturgeon Bay, Wisconsin. Our last surveys occurred in the far eastern Upper Peninsula of Michigan on July 8, 2022 at sites 878 and 915. Cumulatively across all sites and samples, we recorded seven anuran species, including American toad, spring peeper, gray treefrog, green frog, northern leopard frog, wood frog, and bullfrog, which are each relatively common and expected species in Great Lakes coastal wetlands. We did not detect any uncommon or unusual anuran species, and we did not pick up chorus frog, as we did in 2021. At 16 of our 78 total anuran point count surveys, we did not detect any anurans calling at sites that were heavily inundated with water (e.g., sites 915, 1412, 878) or located in heavily urbanized areas (e.g., site 1446).

Extra Sites and Data

Nothing to report.

Wetland Condition Observations and Results (from fall report)

High water levels again made sampling challenging in 2022. Three wetland sites failed to meet project criteria because they were totally covered with water, though we sampled them anyway for the sake of maintaining project sampling continuity across years. Statuses of these wetlands were noted in the online site database as "could not sample" for sites 1412 (Washington Island, Door County, WI), 1747 (between Stonington and Garden Peninsulas in Upper MI), and 915 (Sugar Island, MI).

Although we typically survey one of the highest quality wetlands in the Great Lakes, site 792, almost annually for CWMP, this site was not assigned to our team this year. Instead, we were assigned sites 793 and 796, which are equally as high quality and a part of the same Munuscong River wetland complex as site 792. We accessed both sites via motorboat (793 is a remote island) and collected extremely valuable, high quality bird data. At site 793, our field observers detected target marsh species, including Black Tern, American Coot, Common Gallinule (rare to Upper MI), Marsh Wren, Pied-billed Grebe, Sora, and others. Similarly, at site 796, our team documented Black Tern, Marsh Wren, Wilson's Snipe, Pied-billed Grebe, American Bittern, Common Gallinule, and others.

Data Processing

Summer anuran field technicians have completed double data entry for all 2022 anuran point counts and conducted QC such that all double entries match. Summer bird field technicians have completed double data entry for 2022 bird point count surveys.

Mid-season QC Check Findings (from fall report)

Our team's newest anuran technician was regularly checked throughout the 2022 field season by Erin Giese and Field Crew Leader and Anuran Expert, Brenna Nicholson, to ensure they were collecting data correctly. Erin Giese also regularly checked bird observations reported by the team's newest bird technicians and addressed any issues as needed. However, because our team's two bird technicians were new to bird surveys, Erin spent >100 hours with each of them by training them on bird visual and auditory bird identification both online and regularly in the field.

Audit and QC Report and Findings

Summer anuran field technicians have conducted data QC, such that all double entries match.

Since early April 2023, we have nearly finished conducting QA/QC checks in the Data Verification Interface portal of the CWMP website for all sections except "Missing Site Visits." For the "individual records" review section in the anuran data, most entries were flagged because the "no species observed" box was not checked, which is due to this box being added later to the online data entry system. The remaining flagged anuran entries were due to minor issues such as missing weather data, though at least a few times an incorrect survey date was caught and fixed. We were able to resolve nearly all flagged anuran data and denote the data as usable for any purpose with a few exceptions.

For the "individual records" review section in the bird data, most entries were flagged because the "no aerial foragers" box was not checked, which is due to this box being added later to the online data entry system. The remaining flagged bird entries were due to minor issues such as incorrect minute codes recorded, though at least a few times an error was identified and subsequently fixed. We were able to resolve nearly all flagged bird data and denote the data as usable for any purpose with few exceptions.

Lastly, we investigated the "point sample duration" issues, which flagged point count data when points within the same site, round, and year were conducted beyond a 3-day period. Example: AB1444.1 was surveyed for round 1 anurans on 4/15/2022 but AB1444.2 was surveyed on 4/20/2022 for round 1 anurans. This check is not biologically valid nor is it listed in the project's QAPP. Sometimes it is not logistically feasible to conduct surveys at points in close succession in time within the same site, round, and year. However, an upper limit check should be imposed, such as 2 or 3 weeks, so that we can ensure data are entered correctly.

Additional Funding and Projects

Nothing to report.

Other Collaboration Activities

We contributed major quantitative analyses and writing to the State of the Lakes 2022 Indicator Condition and Trends Report. These results will be expanded in the form of at least two manuscripts that we plan to submit for publication during 2023.

Other Data Requests (from fall report)

In July 2022 Audubon Great Lakes (AGL) requested CWMP bird data to assist them with assessing the impact of National Fish and 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 (BACI) 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 implemented surveys in 2021 and 2022 (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.

Species lists were provided to the Wisconsin Department of Natural Resources in agreement for allowing our team to survey on State Natural Areas.

Related Student Research (from fall report)

UW-Green Bay undergraduate Sarah Baughman initiated a study of birds at river mouths along the west coast of Lake Michigan in Wisconsin. She compared both breeding and migratory birds at these locations with "control" sites nearby along the coast but at least 1 km from a river mouth. Funding for her project came from the Cofrin Center for Biodiversity and the University of Wisconsin Freshwater Collaborative. We also are continuing our research on piscivorous birds in lower Green Bay, with funding from UW Sea Grant. This study employed 10 UW-Green Bay students during summer 2022.

CENTRAL BASIN BIRD AND ANURAN TEAM, CENTRAL MICHIGAN UNIVERSITY

Team Members

- Thomas Gehring, PI, wildlife and landscape ecologist (since 2011)
- Bridget Wheelock, team leader, (since 2012)
- Megan Casler, team leader (since 2022)
- Mary Benjamin, team leader (new 2023)
- Sarah Heimberger, summer field technician (since 2022)
- Undergraduate student technician (new spring 2022)

Training (updated)

Anuran and bird training dates are still being scheduled, but training will be completed before surveys begin. Online testing will be used for identification of anurans by sound. All data collectors will reach 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 (Summer 2022)

The CMU bird/anuran team was assigned 43 sites. 31 sites were sampled. We web rejected 7 sites: 4 sites (434, 467, 520, 1805) because they were islands and did not attempt boating at night for safety reasons, 2 sites (549, 1304) because they were isolated wetlands beyond a walkable distance and had no road access, 1 site (1584) because past access requests have been unsuccessful and the permitting agency did not grant access. We visit rejected 5 sites: 3 sites (458, 541, 1303) because apparent map access did not exist on the ground and had no public road access, 2 sites (597, 661) because they were not wetlands or did not meet the protocol requirements of emergent wetland vegetation with <50% woody vegetation. We surveyed 17 bird/anuran scheduled 2022 sites (459, 460, 461, 512, 517, 537, 547, 588, 607, 1297, 1307, 1314, 1890, 1900, 1903, 1913, 1928), 4 bird/anuran scheduled 2022 resample sites (455, 536, 590, 1863), 6 bird/anuran scheduled 2022 pre-sample sites (432, 435, 538, 1281, 1313, 1651), and 4 bird/anuran benchmark sites (515, 7061, - benchmarked by Dr. Don Uzarski because they represent low and high extremes along the disturbance gradient and have long term data sets; 1598- benchmarked in response to the oil pipeline leak under the straits of Mackinaw, 2018, continued monitoring; 7075- United States Geological Survey (USGS) to monitor restoration progress).

Update

A total of 45 sites have been assigned to the CMU bird and anuran crews for the 2023 field season. Of those sites, 34 are regular schedule, 5 are resamples (432, 467,538, 1303, 1651), 3 are pre-samples (436, 444, 591), and 3 are benchmark sites (515, 7061, 7075). The benchmark sites are Indian Harbor Wetland (7061), East Saginaw Bay Coastal Wetland #5 (515) and Shiawassee Flats (7075). All were requested by Dr. Don Uzarski except Shiawassee Flats; 7061 represents low disturbance and 515 represents high disturbance. Site 7075 was requested as a benchmark by the United States Geological Survey (USGS) to monitor restoration progress. The bird and anuran team will not visit four of the sites; three are distant island sites that are logistically challenging to access (467, 552, 557), and site 1303 is a resample site that was attempted last year but has no access. Note, two of the sites that will not be visited are resample sites (467, 1303). Currently 21 sites will be surveyed. The remaining 20 sites are pending either landowner permission or agency permit approval; the sites will be visited if access is granted.

Panel Survey Results (summer 2022)

Anurans: First sample date – 14 April 2022; Last sample date 7 July 2022

Anurans – 11 species
American Toad (*Anaxyrus americanus*)
Bullfrog (*Lithobates catesbeiana*)
Chorus Frog (Western/Boreal) (*Pseudacris triseriata/Pseudacris maculata*)
Cope’s Gray Treefrog (*Hyla chrysoscelis*)
Fowler’s Toad (*Anaxyrus fowleri*)
Gray Treefrog (*Hyla versicolor*)
Green Frog (*Lithobates clamitans*)
Northern Leopard Frog (*Lithobates pipiens*)

Pickerel Frog (*Lithobates palustris*)
Spring Peeper (*Pseudacris crucifer*)
Wood Frog (*Lithobates sylvaticus*)

Birds: First sample date – 21 May 2022; Last sample date 7 July 2022

Birds – 103+ species
Alder Flycatcher
American Bittern
American Black Duck
American Coot
American Crow
American Goldfinch
American Redstart
American Robin
Bald Eagle
Baltimore Oriole
Barn Swallow
Belted Kingfisher
Black Tern
Black-and-white Warbler
Black-bellied Plover
Black-capped Chickadee
Black-crowned Night Heron
Black-throated Green Warbler
Blue Jay
Blue-winged Teal
Brewer's Blackbird
Brown-headed Cowbird
Canada Goose
Caspian Tern
Cedar Waxwing
Chimney Swift
Chipping Sparrow
Cliff Swallow
Common Gallinule
Common Grackle

Common Loon
Common Merganser
Common Nighthawk
Common Tern
Common Yellowthroat
Dark-eyed Junco
Double-crested Cormorant
Downy Woodpecker
Eastern Kingbird
Eastern Phoebe
Eastern Wood-Pewee
European Starling
Forster's Tern
Fox Sparrow
Gray Catbird
Great Blue Heron
Great Crested Flycatcher
Great Egret
Green Heron
Hairy Woodpecker
Herring Gull
House Sparrow
House Wren
Indigo Bunting
Killdeer
Least Bittern
Magnolia Warbler
Mallard
Marsh Wren
Merlin
Mourning Dove
Mourning Warbler
Mute Swan
Northern Cardinal
Northern Flicker
Northern Waterthrush
Osprey
Ovenbird

Pied-billed Grebe
Pileated Woodpecker
Purple Finch
Purple Martin
Red-bellied Woodpecker
Red-eyed Vireo
Red-winged Blackbird
Redhead
Ring-billed Gull
Rose-breasted Grosbeak
Sanderling
Sandhill Crane
Scarlet Tanager
Song Sparrow
Sora
Spotted Sandpiper
Swamp Sparrow
Tennessee Warbler
Tree Swallow
Tufted Titmouse
Turkey Vulture
Unidentified blackbird
Unidentified duck
Unidentified flycatcher
Unidentified large bird
Unidentified shorebird
Unidentified swallow
Unidentified Tern
Unidentified warbler
Unidentified woodpecker
Veery
Virginia Rail
Warbling Vireo
Whip-poor-will
White-breasted Nuthatch
Willow Flycatcher
Wilson's Snipe
Wood Duck

Wood Thrush
Yellow Warbler
Yellow-bellied Flycatcher
Yellow-bellied Sapsucker
Yellow-headed Blackbird

Extra Sites and Data (summer 2022)

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 1598 was benchmarked in 2018 in response to the oil pipeline leak under the straits of Mackinaw. Sampling continues to monitor the site post-incident. 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. No additional data is collected at any of these benchmarked sites.

Wetland Condition Observations and Results

N/A

Data Processing

As of 1 September 2022 all data has been entered and QC'd with no flags. All GPS coordinates are uploaded and matched.

Mid-season QC Check Findings (summer 2022)

On 20 June 2022, mid-year QC checks were completed for each team lead/data collector (Megan Bos, Megan Casler, Bridget Wheelock) at 2 sites each for anurans and birds this year (only anuran for Bridget Wheelock 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

As of 1 September 2022 all data has been entered and QC'd with no flags. All GPS coordinates are uploaded and matched.

Additional Funding and Projects

N/A

Other Collaboration Activities

N/A

Other Data Requests

N/A

Related Student Research

Megan Casler's M.S. thesis research is examining the 2011-2022 CWMP database to model obligate marsh bird occupancy patterns in the Great Lakes basin. Mary Benjamin's M.S. thesis research will be examining temporal patterns in rail vocalizations in coastal wetlands using autonomous recording units.

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

Central Michigan University
- Dr. Donald Uzarski, lead PI, wetland ecologist (since 2011)
- Bridget Wheelock, Uzarski lab manager, team leader (since 2012)
- Molly Gordon, lead invertebrate taxonomist (since 2011)
- Matthew Sand, water quality technician (since 2020)
- Morgan Noffsinger, graduate student, summer field technician (new 2023)
- Two undergraduate summer field technicians (new 2023)

Grand Valley State University
- Dr. Carl Ruetz, PI, fisheries biologist (since 2010)
- Matthew Silverhart, team leader, QC manager, graduate assistant (since 2020)
- Sunny Charpentier and Colin Assenmacher, summer field technicians (since 2022)
- Brianne Siple and Jacob Yingling, summer interns (since 2022)

Lake Superior State University
- Dr. Ashley Moerke, PI (since 2011)
- Silas Dunn, crew leader and invertebrate taxonomist (new 2023)

- Michael Hillary, team leader, graduate student (since 2022)
- Chris Wedding and Connor Arnold, summer field technicians (new 2023)

University of Notre Dame

- Dr. Gary Lamberti, PI, (since 2011)
- Sarah Klepinger, crew leader, invertebrate taxonomist, lab manager (since 2019)
- Amaryllis Adey, graduate student (new 2023)

Training

Central Michigan University will be hosting the Central Basin fish/invertebrate/water quality training at site 515 in Saginaw Bay on 15 June 2023 and 16 June 2023. The training will be led by CMU crew leader Bridget Wheelock who has been part of the CWMP since 2012 and GVSU crew leader Matthew Silverhart who has been part of the CWMP since 2020. 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 LSSU, GVSU and CMU. Sarah Klepinger and Amaryllis Adey of UND are trained and experienced in CWMP protocols

Silas Dunn from LSSU traveled to Duluth to review invertebrate identification and strengthen his skills with Valerie Brady's team at NRRI. Silas is nationally certified to identify aquatic insects to family level, but he is new to this project and we wanted him to have some additional training especially on non-insect taxa.

Challenges and Lessons Learned (summer 2022)

Water levels remained high in the St. Marys River sites because many of the compensating gates were fully open. As a result, some vegetation zones were too deep to sample and some only had flooded nearshore zones of mixed shrubs and therefore were not sampleable. Other sites that were sampled by CMU had similar issues with water levels remaining high at some sites preventing them from sampling invertebrates and fish in some vegetation zones. The primary issue encountered during the 2022 sampling season for GVSU was handling COVID protocols when two crew members tested positive for COVID-19, which resulted in delays to the field schedule. Additionally, there were a number of sites that did not have easy access, which required alternative methods (smaller boats/hiking) to access those sites.

Site Visit List (summer 2022)

The US Central Basin was assigned 56 sites (24 CMU, 12 GVSU, 12 LSSU, 8 UND), eight of which were benchmarks (515, 815, 1131, 1136, 1598, 7055, 7061 and 7075), seven of which were re-sample sites (455, 536, 590, 778, 878, 915 and 1584). Dr. Don Uzarski requested that five sites were benchmarked. Sites 515 and 7061 were benchmarked because they represent low and high extremes, respectively, along the disturbance gradient and have long term data sets. Sites 1131 and 1136 were benchmarked because they represent high extremes along the disturbance gradient and to make the most out of the Isle Royale trip where there was only one accessible site. Site 1598 is close to the line 5 oil pipeline in the Mackinac Straits and was requested as a benchmark to gather historical data in the event of an oil spill. Site 815 was benchmarked by Dr. Ashley Moerke to document potential effects of an oil spill in the St. Marys River in June. Site 7055 has not been sampled before and was benchmarked by Dr. Valerie Brady to ensure it was sampled by all crews. Site 7075 was requested as a benchmark by the United States Geological Survey (USGS) to monitor restoration progress. We sampled 37 sites, visit rejected 14 and could not access three sites (1584 due to land ownership issues, 1125 and 1144 because they are located on Isle Royale and couldn't be safely accessed due to the long distance from a boat launch).

Update

A total of 45 sites have been assigned to the Central Basin fish/invertebrate/water quality crews for the 2023 field season. Of those sites 37 are panel year sites, 4 are resample sites from the 2022 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.

Central Michigan University was assigned 18 sites for the 2023 season (535, 538, 557, 567, 571, 573, 575, 589, 591, 736, 777, 780, 847, 1546, 1578, 1585, 1598 and 7061). For the 2023 field season the GVSU crew was assigned 12 sites (444, 447, 488, 496, 507, 515, 521, 760, 1282, 1303, 1818 and 7075). Their plan is to assess and sample all sites assigned to the GVSU crew. The LSSU crew was assigned 9 sites for the 2023 season (615, 623, 635, 790, 791, 809, 828, 845, and 922). The UND crew plans to sample sites 432, 436, 1896, 1319, 1651 and 1652 for fish, invertebrates and water quality.

Panel Survey Results (summer 2022)

Sampling started on 13 June 2022 and the last site was sampled on 26 August 2022. The following tables list zones sampled for each site, non-native species by site and reptile species captured in fyke nets, respectively.

Vegetation Zones by Site

Site	Vegetation Zone
432	Sparse bulrush
	Typha
434	*Phragmites*
	Sparse bulrush
435	*Phragmites*
460	*Phragmites*
461	*Phragmites*
	Sparse bulrush
515	*Phragmites*
	Sparse bulrush
	Typha
517	*Phragmites*
	Typha
520	Lily
	Phragmites
	Typha
536	Sparse bulrush
	Typha
537	Dense bulrush
	Phragmites
	Typha
547	Dense bulrush
549	*Typha*
	Wet Meadow
590	Dense bulrush
	Typha
615	Dense bulrush
	Lily
616	Dense bulrush
	Lily
	Typha

637	Dense bulrush
	Lily
	Typha
776	Dense bulrush
778	Dense bulrush
	Phragmites
	Typha
780	Dense bulrush
	Typha
793	Dense bulrush
	Typha
796	Dense bulrush
	SAV
	Typha
804	Lily
	SAV
	Typha
808	SAV
815	Open Water
	SAV
	Typha
862	Lily (*Potamogeton*)
878	Dense bulrush
1130	Tall Dense Spikerush
1136	Dense bulrush
1281	*Typha*
1303	SAV
1304	SAV
1307	Lily
1598	Dense bulrush
	Phragmites
	Typha
1651	*Peltandra / Pontedaria*
	Typha
1903	Lily
	Typha
1913	Lily
1928	*Phragmites*
7055	Dense bulrush
	Typha

7061	Dense bulrush
	Wet Meadow
7075	Lily
	Peltandra / Pontedaria
	Typha

Non-native Species by Site

Site	Common Name	Taxa name
432	Round Goby	*Neogobius melanostomus*
461	Round Goby	*Neogobius melanostomus*
515	Round Goby	*Neogobius melanostomus*
	White Perch	*Morone americana*
536	Round Goby	*Neogobius melanostomus*
537	Round Goby	*Neogobius melanostomus*
615	Round Goby	*Neogobius melanostomus*
	Rusty Crayfish	*Orconectes rusticus*
778	Freshwater Tubenose Goby	*Proterorhinus semilunaris*
815	Rainbow Smelt	*Osmerus mordax*
1303	Round Goby	*Neogobius melanostomus*
1651	Round Goby	*Neogobius melanostomus*
1903	Common Carp	*Cyprinus carpio*
	Round Goby	*Neogobius melanostomus*
7055	Common Carp	*Cyprinus carpio*
7061	Round Goby	*Neogobius melanostomus*
7075	Round Goby	*Neogobius melanostomus*

Reptile Species Captured in Fyke Nets

Common Name	Taxa name
Common Snapping Turtle	*Chelydra serpentina*
Northern (Common) Map Turtle	*Graptemys geographica*
Painted Turtle	*Chrysemys picta*
Spiny softshell	*Apalone spinifera*
Stinkpot (Common Musk Turtle)	*Sternotherus odoratus*

Extra Sites and Data (summer 2022)

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. 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. Sites 1131 and 1136 were benchmarked because they represent high extremes along the disturbance gradient. These data will be used for developing and improving our indices of biotic integrity and indices of environmental condition. Site 1598 is close to the line 5 oil pipeline in the Mackinac Straits and was requested as a benchmark to gather historical data in the event of an oil spill. Site 815 was a late site add to document possible impacts due to an oil spill in the St. Marys River. Three zones were sampled, but one (SAV) was quarantined because it did not meet the vegetation zone requirements.

Extra soil cores and water samples were collected by CMU and LSSU (soil cores only) at all sampled sites for microplastics 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 and measured dissolved oxygen, water pressure, air pressure, water temperature, air temperature. These data were sent to Nathan Tuck and Dr. 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.

An LSSU undergraduate deployed detritus packs to quantify decomposition in 2021. He pulled most of the packs by end of 2021, but he left one set and pulled these in 2022. These data were not included in the database.

<u>Update</u>

The CMU crew will collect syringes full of water at every replicate for dissolved gas and microplastics analysis.

Wetland Condition Observations and Results (summer 2022)

The CMU team noticed that water levels were down but there were still some deep zones that could not be sampled for invertebrates or fish (predominantly Lily and *Schoenoplectus* zones). They also noticed that there seemed to be less separation between vegetation zones (more mixed) than in recent years. Overall, the wetlands sampled by the GVSU team were accessible and were mostly intact. For LSSU water levels were relatively low early in the season (i.e., early June) but they raised quickly and remained high throughout the sampling season. This made some zones challenging to sample due to the high water levels. The UND team found that some of the sites they surveyed seemed quite polluted, as they were sampling in predominantly industrial areas near Toledo. They saw a lot of garbage, like foam packaging, appliances, and construction materials. The water was opaque and mucky. Their sites in Anchor Bay were free of trash and other evidence of human activity, except for recreational boat traffic. People they encountered often seemed curious about what they were doing. Even when initially met with suspicion, once their motives and qualifications were explained, people became supportive. They responded positively when they explained that they were there to determine wetland health, and to keep them in good shape for fish and wildlife to utilize. The most common questions were regarding which fish were caught and where they caught them, as has been 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, received (mid-February), entered and QA'd for all crews. Twenty GVSU chlorophyll-a samples were mailed to the Lamberti Lab at the University of Notre Dame on 6 September 2022 for processing. Results from laboratory processing were entered into the database and QA'd in February 2023 by CMU. Water analysis results were received from CMU in late February and entered into the database and QA'd. Sixty GVSU water samples (raw, filtered nutrients, and dissolved ions) were delivered to Bridget Wheelock at Central Michigan University by Colin Assenmacher (seasonal technician) on 1 September 2022. Results from laboratory processing were entered into the database and QA'd in March 2023 by Brianne Siple (undergraduate summer intern) and Matthew Silverhart. Macroinvertebrate identification has been completed by the UND lab. Macroinvertebrate ID has begun at LSSU, but will be behind schedule due to a change in personnel. ID is expected to be completed by early April. Twelve GVSU macroinvertebrate samples were given to Bridget Wheelock from Central Michigan University on 14 June 2022 at the wetlands training of site 515. Forty-seven additional GVSU macroinvertebrate samples were delivered to Bridget Wheelock at Central Michigan University by Colin Assenmacher (seasonal technician) on 1 September 2022. The CMU lab has finished initial macroinvertebrate IDs from the CMU and GVSU 2022 sites. All of the CMU macroinvertebrate samples have been QA'd, entered into the database and QA'd in the database. 11% of the GVSU macroinvertebrate QA's have been completed, entered into the database and QA'd in the database. Sample processing at CMU is expected to be finished by May of 2023. When all macroinvertebrates are identified and QA'd we will trade samples with our collaborating QA laboratory. We are also working through the data verification reports to correct past data entry or collection errors. We will have this task completed by end of March.

Mid-season QC Check Findings (summer 2022)

The CMU mid-season check occurred 20 July 22 and 21 July 22 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 was scheduled to occur but was unable to be completed as Dr. Carl Ruetz had COVID-19 and was unable to safely participate in the mid-season QC check. Crew leader Matthew Silverhart was with the GVSU field crew during all stages of sampling and observed that sampling occurred in accordance with the SOP. The LSSU mid-season check occurred 12 July 22 and no issues were noted. The crew was correctly sampling and identifying fishes in the field.

Audit and QC Report and Findings (updated)

The team has been working through data validation interface issues on data from 2016 – 2021.

Additional Funding and Projects (from fall report)

For LSSU, there were three undergraduate projects discussed below.

Other Collaboration Activities (summer 2022)

GVSU collaborated with the University of Michigan, USGS and the US Fish and Wildlife Service to sample site 7075. LSSU continues to collaborate with Matt Cooper on an undergraduate project. Moerke was on the planning team for the Great Lakes Coastal Symposium that was held in Sault Sainte Marie, MI on 19 September 22 through 21 September 2022.

<u>Update</u>

The Coastal Symposium conference was held in Sault Sainte Marie, MI on Sept 19-21, 2022. An evening reception was held at LSSU's Center for Freshwater Research and Education and had over 100 participants.

Other Data Requests (summer 2022)

Central Michigan University received a few requests for data in 2022. A Masters student from U of M-Flint requested water quality data from site 7075 (Shiawassee River Wetland) to compare to the Flint River's water quality. A Ph. D student from University of Pittsburgh requested a list of sites where duckweed species were present as they are interested in tracking the species composition to answer questions about coexistence and evolutionary history. A retired biologist in New York requested locations of pirate perch in Michigan in order to get a better perspective on this species, as it is recommended to be classified as threatened in New York. He plans to compare this species' range in New York, to where it was also found in Michigan in proximity to Lakes Michigan and Huron.

Related Student Research (updated)

Two CMU undergraduate students (Julia Shablin and Miranda England) are looking at microplastics composition in soil and additional water samples collected by CMU and LSSU at all sampled 2022 sites. Matthew Silverhart, a graduate student and crew leader at GVSU, is using data collected throughout the GLCWMP for his thesis on the influence of monodominant plant zones on fish community distribution within Great Lakes coastal wetlands. Michael Hillary, undergraduate student at LSSU, is quantifying litter decomposition and respiration rates in wetlands of varying health. Michael is also collaborating with Dr. Matt Cooper. Michael presented a poster at the Joint Aquatic Sciences Meeting this past June and completed his second year of sampling this summer.

Update

Michael from LSSU presented at the Joint Aquatic Sciences Meeting and he is working on submitting his research for publication to the Journal of Great Lakes Research.

Incoming graduate student Morgan Noffsinger will be conducting fish research alongside CMU CWMP crews. Undergraduate Marta Kendziorski (fish/invertebrate/water quality crew member 2022) will be doing a capstone project looking at relationships between different taxa within the CWMP using 2011-2022 CWMP data.

CENTRAL BASIN VEGETATION TEAM, CENTRAL MICHIGAN UNIVERSITY

Team Members

Update

- Dr. Dennis Albert, PI, wetland vegetation ecologist/botanist (since 2011)
- Matthew Sand, crew leader, wetland plants and water chemistry (since 2017)
- Kimberly Schraitle, crew leader, wetland plants (since 2022)
- Emily Schultheis, CMU summer field technician (since 2022)
- Emma Waatti, CMU graduate student crew leader, wetland plants (new 2023)
- One CMU summer field season technician (new 2023)

Training

From Fall Report

Allison Kneisel (5 years of crew leader experience), Matthew Sand (3 years of crew leader experience), and Olivia Anderson (1 year of crew leader experience) trained the 2 new technicians in Mt. Pleasant wetlands from June 15th – June 17th, 2022. Topics covered included: identification of common Michigan coastal wetland macrophytes, proper use of GPS for taking waypoints, using a compass to set transect bearings, percent cover estimation, collection of plants for expert ID, and completion of datasheets.

Allison Kneisel, Matthew Sand, and Olivia Anderson trained Kimberly Schraitle (newly hired Uzarski laboratory manager) and two new summer field technicians on *in-situ* vegetation sampling protocols at Toledo Beach Wetland in Monroe, MI on June 21st, 2022. They also calibrated individual percent cover estimates.

On June 24th, 2022, the crew met with Dr. Dennis Albert via webinar to discuss the upcoming sample year and ask questions about macrophyte identification and sampling protocols. Following the meeting, crew members were tested on a subset of specimens covered in training PowerPoints and collected from Mt. Pleasant wetlands. Crew leaders Olivia Anderson and Matthew Sand both correctly identified 100% of the specimens.

<u>Update</u>

Kim Schraitle or Matt Sand will lead a training on the sampling protocol in mid-June, and Dr. Dennis Albert will lead a virtual plant identification training in late June for the 2023 field season.

Challenges and Lessons Learned

From Fall Report

Due to water levels dropping from the previous high-water years of 2020 and 2021, the patterns of vegetation zonation continue to be in flux within the wet meadow, emergent, and submergent vegetation zones. When samplers were unclear on how to treat zones, they sent pictures to one of the more experienced crew leaders for confirmation and included information on the zonation in the notes section of datasheets. At some sites, crews also experienced difficult or dangerous sampling conditions due to the drop in water levels. One site in particular, Stony Creek Wetland (1303), was rejected because the receding water level exposed thick, mucky sediment that was dangerous to canoe or wade through.

Figure 35. Receding water levels left Stony Creek Wetland (1303) inaccessible in 2022.

<u>Update</u>

PIs held discussions about updating the SOP to consider percent coverage values of 0.5%. Consensus is that current percent cover protocols are adequate for accurate use of clustering algorithms and statistical analysis of the vegetation database, but that minor clarifications may be added to streamline data entry and quality control.

Next season, safety training will expand upon keeping underrepresented individuals safe during sampling and traveling.

Site Visit List

From Fall Report

The Central Basin vegetation crews sampled 43 sites: 25 panel sites from 2022, 6 resampled panel sites from 2021, 6 pre-sampled panel sites from 2023, and 6 benchmark sites. Five of the benchmarks were requested by Dr. Don Uzarski: East Saginaw Bay Coastal Wetland #5 (515), Tobin Harbor Creek Wetland (1131), Moskey Basin Campground Wetland (1136), Indian Harbor Wetland (7061), and Point St. Ignace Wetland (1598). Many of these sites represent extremes along the disturbance gradient. Site 515 is highly disturbed, while sites 1131 and 1136 are characterized by low levels of disturbance, as is the long-term benchmark site 7061. Point St. Ignace Wetland (1598) is being monitored as a benchmark to track potential environmental changes in the Straits of Mackinac. Lake George West Shore Wetland #1b (7055) was requested as a benchmark by Dr. Valerie Brady to ensure this site was sampled.

Crews could not access 2 sites due to either landowner permissions (538) or access issues (1303). Property owners were not present to request sampling permission at Whitefish Bay Wetland (538) where "No Trespassing" signs were posted. Stony Creek Wetland (1303) was rejected as inaccessible due to deep, fine-textured, saturated sediments.

<u>Update</u>

Forty-seven sites have been assigned the Central Basin vegetation crew for the 2023 field season. Of those sites, 6 are panel year sites, 4 are resample sites from the 2022 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 and Dr. Denny Albert; 7061 represents low disturbance, 515 represents high disturbance, and 1598 is being monitored due to potential environmental changes in the Straits of Mackinac.

Panel Survey Results

From Fall Report

In the US Central Basin, the first day of vegetation sampling took place on June 20th, 2022 and the last day of sampling took place on September 14th, 2022. While specimen identifications and species lists are still underway, in general we noted few expansions of invasive species and few new sites for threatened species. Exceptions are in Indian Harbor Wetland (7061) where a new population of invasive *Myriophyllum spicatum* (Eurasian watermilfoil) was identified, in Munuscong Lake Wetland #6 (796) where state-threatened *Rorippa aquatica* (water cabbage or lake cress) was identified, and in Duncan Bay Wetland (1130) where state-endangered *Subularia aquatica* (water awlwort) was identified. The drop in water levels exposed new areas of wet meadow, resulting in a major increase in the number of native wet-meadow species.

<u>Update</u>

The three panel sites with the highest species richness are South Scott Bay Area Wetland (780) with 100 species, Paw Point-North Scott Bay Wetland (778) with 88 species, and Mill Pond Wetland (615) with 83 species. Harsen's Island Wetland (435) was sampled for the first time in this program on June 28th, 2022. This site has not been sampled in the past due to too many sites being assigned for those years. Common invasive species including *Hydrocharis morsus-ranae* (frog bit), *Lythrum salicaria* (purple loosestrife), *Myriophyllum spicatum* (Eurasian watermilfoil), *Phragmites australis*, *Typha angustifolia (*narrow-leaf cattail), *Typha X glauca (hybrid cattail), and* Charophyte algae *Nitellopsis obtusa* (starry stonewort) were found across the central basin area. The documented population of *Myriophyllum spicatum* at Indian Harbor Wetland (7061) was new to the GLCWMP database; however, the University of Michigan Herbarium documented this species in St. James on Beaver Island in 1965. Duncan Bay (1130) was also sampled for the first time where state-endangered *Subularia aquatica* was identified. *S. aquatica* is a small submergent plant of northern, soft water lakes, typically found in shallow, clear waters or occasionally along newly exposed shorelines. It is likely under collected and may be more abundant than collections indicate. This site has not been sampled in the past due to its remote location and planning requirements.

Invasive species found during 2022 sampling:

Invasive Species	**Sites**
Acorus calamus	615
Agrostis gigantea	536, 537, 780, 7061
Butomus umbellatus	1913

Cirsium arvense	796, 1281
Frangula alnus	537
Hydrocharis morsus-ranae	460, 515, 520, 537, 590, 793, 1903, 1913, 1928
Linaria vulgaris	590
Lysimachia nummularia	590, 807, 1651
Lythrum salicaria	537, 780, 807, 878, 901, 1281, 1304, 1651, 7055
Myriophyllum spicatum	455, 460, 537, 590, 615, 793, 804, 1304, 1651, 1903, 1913, 7061
Nitellopsis obtusa	432, 434, 460, 520
Persicaria lapathifolia	778, 807
Persicaria maculosa	537, 649, 780, 807
Phalaris arundinacea	590, 615, 616, 744, 780, 862, 901, 1130, 1281, 1304, 1651, 1913
Phragmites australis	432, 434, 435, 460, 515, 517, 520, 536, 637, 649, 778, 780, 878, 1913
Poa compressa	541, 776
Potamogeton crispus	460, 1281, 1304, 1651, 1903, 1913
Typha angustifolia	460, 615, 616, 778, 862, 1281, 1598, 1903, 1913
Typha glauca	435, 517, 536, 537, 590, 615, 616, 637, 776, 780, 793, 796, 804, 1281, 1598, 1651, 1913, 7055, 7061

Site 869 data from 2021 and 2022 were quarantined due to the presence of only a sparse submergent zone. Site 915 data from 2021 and 2022 were quarantined due to erosion and being drowned out. Site 915 was removed from further sampling.

Extra Sites and Data

From Fall Report

Benchmark site East Saginaw Bay Coastal Wetland #5 (515) was sampled on September 14th, 2022. It was selected as a benchmark to track long-term trends at a site that was highly degraded throughout earlier long-term sampling. This site continued to be dominated by invasive *Phragmites australis* during 2022 sampling, with few other species encountered.

Benchmark site Tobin Harbor Creek Wetland (1131) was sampled on August 24th, 2022 and benchmark site Moskey Basin Campground Wetland (1136) was sampled on August 25th, 2022. These sites were selected as benchmarks to track high-quality sites over the long-term. A notable change was the disappearance of emergent vegetation at Moskey Basin since 2017.

The high-quality Indian Harbor Wetland (7061) benchmark was sampled on July 20th, 2022. The only obvious change at this site from 2021 sampling was the presence of invasive *Myriophyllum spicatum*.

Point St. Ignace Wetland (1598) was sampled on July 18th, 2022 to track potential environmental changes in the Straits of Mackinac, but no notable changes were observed from previous years.

The data for all these sites will be entered into GreatLakesWetlands.org web site.

Update

Indian Harbor Wetland (7061) had the highest richness of the benchmark sites with 69 species. South Scott Bay Area Wetland (780) had the highest richness of all sampled sites with 100 species. Each transect at this site had three distinct zones with a large variety of species in each.

The data for these sites has been entered GreatLakesWetlands.org.

Wetland Condition Observations and Results

From Fall Report

The most visible trend noted by sampling crews is that the vegetation zonation was impacted by receding water levels. In many sites, the remains of dead woody plants persist in the wet meadow and emergent zones. For example, at Island #1 St. Mary's River Wetland (915), still-inundated meadows contained large amounts of dead *Myrica gale*. There were also many more seedlings in the wet meadow zones this year than in either 2020 or 2021 due to the increased area of exposed moist, aerated, organic-rich sediments.

Figure 36. *Myrica gale* in an inundated meadow at Island #1 St. Mary's River Wetland (915) in 2022.

Data Processing

All 2022 vegetation data has been entered into GreatLakesWetlands.org and quality checked by PI Dennis Albert.

Mid-season QC Check Findings

From Fall Report

Matthew Sand joined Olivia Anderson and her crew on August 8th, 2022 in St. Mary's River to evaluate sampling procedures. No corrections were needed for the sampling crew. Crews have also shipped unknown plants to Dr. Dennis Albert for confirmation throughout the summer.

Audit and QC Report and Findings

All 2022 vegetation data has been entered into GreatLakesWetlands.org and quality checked by PI Dennis Albert.

Data from 2016-2021 were checked for errors using the Data Verification Interface. Errors were either corrected and marked as usable for any purpose or marked as usable for research purposes only.

Additional Funding and Projects

There is no additional funding to report for the 2022 field season.

Other Collaboration Activities

There are no external collaboration activities to report for the 2022 field season.

Other Data Requests

From Fall Report

Lists of species encountered in 2021 from Steel Creek Wetland (613), Duck Bay Wetland (619b), and Hog Island Wetland (815) were sent to the Little Traverse Conservancy in exchange for permission to sample Mackinac Creek Wetland (616) in 2022.

The National Park Service requested that specimens collected from Isle Royale wetlands (1130, 1131, and 1136) be pressed and preserved for historical collection. These plants were prepared and stored in the Central Michigan University Herbarium.

Update

Matt Sand submitted an Investigator's Annual Report to the National Parks Service for Isle Royale wetlands (1130, 1131, 1136). Detailed in this report were the locations and dates of field work, vegetation zones and depths sampled, and a list of taxa found. This report was sent in compliance with scientific study permitting for the NPS. Reports containing the same information will be sent to Little Traverse Conservancy (for site 616) and Saginaw Bay Land Conservancy (for site 460) prior to 2023 sampling. These will be submitted with a permission request to sample on conservancy land in 2023.

Related Student Research

Data from 2022 is not currently being used in any student research projects.

CENTRAL/EASTERN BASIN BIRD AND ANURAN TEAM, BIRDS CANADA

Team Members

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

Training

All four field crew members / contractors will receive training refreshers via webinar or phone in early April 2023. Topics will include site selection and station placement; anuran and bird survey field protocols; reporting; safety procedures; 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

Field work in 2023 looks straightforward for us. We foresee no issues with COVID-19 and many of the sites we have visited in multiple previous years.

Site Visit List

We are considering 58 sites for sampling in 2023, which consist of 53 panel, 3 resample, and 2 special-request benchmark sites. We will attempt to survey 47 of these 58 sites. We are unable to survey 11 of the sites due to the following:

- issues with obtaining landowner access (2 sites)
- safety (9 sites)

Panel Survey Results

From previous report: Sampling for anurans occurred from 11 April until 2 July 2022 and sampling for birds occurred from 20 May to 7 July 2022. Of note were 72 point occurrences of 7 Ontario bird species at risk or of conservation concern.

		No. Occurrences	
Species	**ON-ESA/SARA Status***	**2021 (*n* = 42 sites)**	**2022 (*n* = 40 sites)**
Bald Eagle	Special concern	16	4
Bank Swallow	Threatened	14	7
Barn Swallow	Threatened	40	27
Black Tern	Special concern	12	4
Chimney Swift	Threatened	4	4
Common Nighthawk	Threatened	1	0
Eastern Meadowlark	Threatened	0	1
Least Bittern	Threatened	14	25
Red-headed Woodpecker	Endangered	1	0
Total		102	72

*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 (we also logged 2 occurrences in 2021).

Extra Sites and Data

From previous report: We did not sample any benchmark sites in 2022.

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 previous report: We noted that lake levels in 2022 were lower than in 2021 at many of our sites, although levels were higher than most years during the past decade. Like the previous year, we sensed that abundance of secretive marsh birds was lower in 2022 at sites with suitable emergent vegetation likely because of the lower lake 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

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

Mid-season QC Check Findings

Mid-season checks will be performed in mid-June.

Audit and QC Report and Findings

No issues to report.

Additional Funding and Projects

We secured additional funding from Environment and Climate Change Canada to augment the bird and anuran team's capacity to complete a bird 10-year trend analysis using all of the CWMP data in Canada and the US. This project is described further in the next section.

Other Collaboration Activities

The CWMP bird and anuran team collaborated with Danielle Ethier, the Bird Population Scientist at Birds Canada in Port Rowan, Ontario, to complete a bird 10-year trend analysis using all of the CWMP data in Canada and the US. The project reports population trends for a large suite of bird species in different catchments relevant to conservation and management. The draft title and abstract from the paper, which will soon be submitted to a peer-reviewed journal, is reproduced here for interest:

Marsh-breeding bird abundance indices and population trends in Great Lakes coastal wetlands: 2011–2021

Marshes of the Laurentian Great Lakes basin of North America are critical for bird conservation. Here, for the first time, we quantify abundance indices and population trends of 18 marsh-breeding bird species in coastal wetlands throughout the entire Great Lakes basin using 11 years (2011–2021) of data collected at 1,962 sample points in 792 marshes by the Great Lakes Coastal Wetland Monitoring Program. Despite previously documented population declines for many of the species in the southern portion of the Great Lakes basin since the mid-1990s, we found that 12 species (67%) increased in at least one of the Great Lakes by 5–50% per year, whereas only 3 species (17%) decreased by 2–10% per year. There were far more positive trends among lakes and species (n = 34, 48%) than negative trends (n = 5, 7%). Population changes were probably linked, at least in part, to concurrent changes in lake levels, which are known to positively influence all but one of the increasing species and negatively influence all of the decreasing species. While population increases are beneficial for many of the species, which are of conservation concern, we caution that Great Lakes water levels are highly dynamic making it challenging to predict future changes in marsh-breeding bird abundance. Permanent protection, restoration, and enhancement of remaining Great Lakes coastal wetlands is, therefore, a priority to ensure adequate amounts of high-quality marsh-breeding bird habitat, especially during what appear to be high-lake-level-induced population pulses for some species

The CWMP bird and anuran team also published a paper in Ecosphere based in part on CWMP bird data from a chapter of Lisa Elliott's PhD thesis. The title and abstract are reproduced here for interest:

Application of habitat association models across regions: explanatory power retained in a case study of wetland birds

Species often exhibit regionally specific habitat associations, and thus, ecologists need to understand how well habitat association models developed in one region perform elsewhere. Three North American wetland breeding bird survey programs in Great Lakes coastal wetlands, inland Great Lakes wetlands, and the Prairie Pothole Region offer an opportunity to test whether regionally specific models of habitat use by wetland-obligate breeding birds are transferrable across regions. We first developed independent, species-specific models of density for each study region for four species of wetland-obligate birds: Pied-billed Grebe (*Podilymbus podiceps*), Virginia Rail (*Rallus limicola*), Sora (*Porzana carolina*), and American Bittern (*Botaurus lentiginosus*). We then used adjusted pseudo-R2 values to compare the amount of variation explained by each model when it was applied to data collected in each of the three regions. Although certain habitat characteristics, such as emergent vegetation and

wetland area, were consistently important across regions, each species' models differed by region—both in variables selected for inclusion and often in the directionality of relationships for variables in common—suggesting that habitat associations for these species are regionally specific. When we applied a model developed in one region to data collected in another region, we found that explanatory power was reduced in most (71%) of the models. Therefore, we suggest that ecological analyses should emphasize the use of regionally specific habitat association models whenever possible. Nonetheless, models created from inland Great Lakes wetland data had higher median explanatory power when applied to other regions, and the degree of explanatory power lost by other transferred models was relatively small. Thus, while regionally specific habitat association models are preferable, in the absence of regional data, it is feasible to cautiously apply models of habitat associations developed in one region to another region. Additionally, we found that median explanatory power was higher when local-scale habitat characteristics were included in the models, suggesting that regionally specific models should ideally be based on a combination of local- and landscape-scale habitat characteristics. Conservation practitioners can leverage such regionally specific models and associated monitoring data to help prioritize areas for management activities that contribute to regional conservation efforts.

And finally, the CWMP bird and anuran team published a third paper based on CWMP bird data, as follows:

Marsh birds as ecological performance indicators for Lake Ontario outflow regulation

Water-level regulation can have significant impacts on coastal wetland ecosystems. In this study we sought to update marsh-bird-based ecological performance indicators (PIs) that support adaptive management of long-term outflow regulation for Lake Ontario. Previous PIs established in the mid-2000s were based on single species and monitoring them required data not currently being collected at broad scales. We therefore focused on developing and validating community-level PIs using data from an ongoing, long-term, basin-wide monitoring program, the Coastal Wetland Monitoring Program (CWMP). After identifying species with documented responses to variation in water levels in the literature, we considered a suite of potential PIs by first examining correlations with both annual mean water levels and measures of inter annual water-level fluctuations. We then used a mixed-modelling framework to determine which highly correlated PIs exhibited statistically significant relationships with water-level variables. Having established significant effects of water levels on the candidate PIs, we performed a power sensitivity analysis to determine the degree of change in each PI that can be detected based on current CWMP sampling. From these analyses, we propose six potential marsh-bird based PIs: sum total abundance of sensitive marsh-obligate species, richness of sensitive marsh-obligate species, and abundance of each of red-winged blackbird (*Agelaius phoeniceus*), marsh wren (*Cistothorus palustris*), common gallinule (*Gallinula galeata*), and least bittern (*Ixobrychus exilis*). Of these, the community-based PIs of sum total abundance and richness of sensitive species appear most suitable for assessing the marsh-bird community response to outflow regulation on Lake Ontario.

Other Data Requests

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

Related Student Research

We continued to provide 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

- Jan Ciborowski, PI, aquatic ecologist (since 2011)
- Joseph Gathman, co-PI, aquatic ecologist (since 2011)
- Paul Weidman, co-PI, limnologist (since 2021)
- Li Wang, Data Management leader (since 2011)
- Michael Dobrin, Invertebrate taxonomist (since 2011)
- Stephanie Johnson, permanent field & lab crew member (since 2016)
- Emilee Mancini, permanent field & lab crew member (since 2018)
- Julia Santin, summer field crew member (new 2023)
- 1-2 workstudy students (new 2023)

Training

With the exception of 1-2 new recruits who will be hired for the coming field season, the individuals who will participate in fieldwork in 2023 were involved in sampling during the 2022 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 2023 and are expected to conduct pilot sampling at local sites on Lake Erie during late May and early June, including sampling sites in western Ohio. Key members of the Windsor field crew from 2022 will be involved in field work in 2023 (including fish, invertebrate and water quality lead Joe Gathman and vegetation lead Carla Huebert). 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.

Returning field team member Emilee Mancini and new recruit Julia Santin will take 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. Other team members already have this training. Team members will receive refreshers in field and lab safety training.

Challenges and Lessons Learned

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 2020-22. Returning crew members are fully trained in both these new guidelines and in the revisions outlined in the 2023 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 previous years, we will sample SAV zones, but only when there are no other zones to sample.

Site Visit List

We anticipate sampling 33 sites during the 2023 field season, three of which are benchmark sites (5762 (Point Pelee Marsh 2), 1847 (Mentor Marsh), and 5422 (Hillman Marsh).

Sites for 2023 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 2023. However, given the continuing risks of COVID 19 transmission, we expect that our requests for access to First Nations lands will be denied.

Extra Sites and Data

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.

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

Non-native Species

Non-native fish species were caught at 5 of the 8 sites that were sampled for fish. Round Gobies (*Neogobius melanostomus*) were found at Carruthers Creek (5160; 4 individuals), Pine Point 1 (5735; 3 individuals), Presqu'ile 1 (5775; 4 individuals), Presqu'ile 13 (5779; 1 individual), and Sawguin Creek 5 (5873; 7 individuals). One Alewife (*Alosa pseudoharengus*) was found at Pine Point 1 (5735). No Common Carp were captured this year.

Reptiles

Eastern Snapping Turtles *(Chelydra serpentina)* were caught at Carruthers Creek (5160; 1 individual) and Wilmot Rivermouth (6073; 1 individual). Painted Turtles (*Chrysemys picta*) were recorded at Pine Point 1 (5735; 2 individuals), Presqu'ile 1 (5775; 3 individuals), Presqu'ile 11 (5777; 2 individuals), Presqu'ile 13 (5779; 2 individuals), Sawguin Creek 5 (5873; 1 individual), and Wellers Bay 12 (6033; 1 individual).

Data Processing

All data collected in 2022 have been processed, QC'ed and entered into the CWM database. In addition, extensive work has continued to review data collected annually since 2019 from water level, dissolved oxygen and light/temperature loggers at wetlands where fyke nets were set. Several labs have used these loggers annually and contributed their data to the repository maintained at the University of Windsor. These data are being supplemented with records of local weather conditions at time of sampling, downloaded from the nearest NOAA and Canadian Weather Service weather stations. We anticipate updating and distributing a guide for standard methods in deployment for other groups who may wish to collect such data to improve comparability of records.

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 6 years experience with the CWM teams.

Audit and QC Report and Findings

Samples of aquatic invertebrates are being exchanged with partner institutions and QCed for accuracy of identification and counts.

Additional Funding and Projects Project Leverage Examples

Nothing to report.

Other Collaboration Activities and Collaborations

Nothing to report.

Other Data Requests

Nothing to report.

Related Student Research

Three graduate students are continuing their part-time, CWMP-related work with Paul Weidman in GLIER at UWindsor. PhD student, Pengfei Hou (visiting student from Yunnan University), is continuing to use remote sensing and spatial modeling to analyze variation in coastal wetland area and depth in nearshore regions of western Lake Erie. Postdoctoral fellow, Dr. Dylan Xia, will be conducting a 6-month project on analyzing spatial and temporal coherence in young-of-the-year forage fish in nearshore regions and coastal wetland sites in western Lake Erie. PhD student, Mona Farhani is starting to use machine learning approaches to analyze land use effects on water quality in coastal wetlands and nearshore regions of western Lake Erie. Each of these students will be contributing one, CWMP-related manuscript in total.

Related Research in Progress

Nothing to report.

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

Team Members

- Jan Ciborowski, PI, aquatic ecologist (since 2011)
- Joseph Gathman, co-PI, aquatic ecologist (since 2011)
- Paul Weidman, co-PI, limnologist (since 2020)
- Li Wang, Data Management leader (since 2011
- Carla Huebert, Vegetation field lead and taxonomist (since 2011)
- Stephanie Johnson, permanent field and lab crew member (since 2016)
- Emilee Mancini, permanent field and lab crew member (since 2019)
- Justin Santin, field crew member (new 2023)

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 2023 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. Four members of the Windsor field crew from 2022 will be involved in field work in 2023. They will train new crew member Julia Santin. Other review for returning field crew members 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)

In the previous three years, high lake levels presented several challenges to our efforts. However, in 2022, levels were notably lower than these previous years: according to the Great Lakes Water Level Dashboard managed by Great Lakes Environmental Research Laboratory (https://www.glerl.noaa.gov/data/dashboard/GLD_HTML5.html) the 2022 annual peak in Lake Huron was approximately 20 cm lower than in 2021 (and 64 cm lower than in 2020), and Lake Erie was approximately 13 cm lower than in 2021 (and 42 cm lower than 2020). Because of the declining levels we did not have the challenges presented in earlier years.

In our report from one year ago, we noted that 2021 weather had been unusually windy, rainy, and cold. In 2022, however, weather/wave conditions were more typical of earlier years, so we had little difficulty with weather or boating conditions.

Site Visit List (updated)

We anticipate sampling 33 sites during the 2023 field season, three of which are benchmark sites (5762 (Point Pelee Marsh 2), 1847 (Mentor Marsh), and 5422 (Hillman Marsh).

Panel Survey Results and Benchmark sites (from fall report)

Vegetation sampling for the UWindsor team began on June 21st, 2022 and ended on September 14th, 2022. A total of 30 sites were sampled, including 26 panel sites, 2 resample sites, and 2 benchmark sites.

The meadows at these wetlands are continuing their regeneration process, and some exciting and uncommon plants were surveyed, including several Spike-Rush species (*Eleocharis flavescens, E. ovata, E. intermedia*), Smith's Bulrush *(Schoenoplectiella smithii)* and Slender Flatsedge (*Cyperus bipartitus*). Carpets of *E. acicularis* were observed at several of these recently exposed wet meadows, along with many other more common species characteristic of recently exposed shores.

A marked decrease in water levels also permitted full-transect sampling of emergent zones again. In previous high-water years, it became unsafe to sample many *Phragmites* and/or *Typha* emergent zones due to the water being over the sampler's head, allowing for partial zone or outer zone sampling only. For the majority of sites in 2022, the full length of these zones could be traversed and sampled again safely (and for the most part, dryly).

Invasive species: The vegetation team did not observe any range expansions of invasive species at their sites in 2022.

Species at risk: American Water-willow (*Justicia americana*; COSEWIC Status: Threatened), was observed again in 2022 at Point Pelee Marsh 2 (5762). It had also been found in several areas of the site throughout the four years the site has been sampled, beginning in 2019. Swamp Rose Mallow (*Hibiscus moscheutos*; COSEWIC Status: Special Concern) was found at two sites in 2022: Point Pelee Marsh 2 (5762) and Lake St. Clair Marshes (5512). It had been found throughout the Point Pelee Marsh in the four previous years that the site has been sampled; however, this was the first time that the species has been found at Lake St. Clair Marshes. The vegetation crew had a chance to speak with the landowner of part of the wetland, and he informed the crew that a large restoration and *Phragmites*-removal project had taken place several years earlier. This restoration area was in the vicinity of where the species was observed.

Benchmark sites: Point Pelee Marsh 2 (5762), in Point Pelee National Park, was sampled for the fourth time in 2022 in cooperation with Parks Canada, which is conducting a 5-year restoration project to increase the amount of open water area at Point Pelee. In 2018, the barrier beach which protected the marsh broke open during a series of strong storms/ seiche events, and the breach had remained open since that time. One result was that the formerly vegetated area near the breach became devoid of vegetation while nearby areas exhibited less vegetation density. A bathymetric survey that our lab conducted in 2018 indicated that a considerable amount of sand had been washed into the wetland in the area near the breach. However, in 2022 the vegetation crew observed that the barrier beach has re-formed and the marsh is once again hydrologically disconnected from Lake Erie. The re-formed barrier beach was measured to be approximately 60 metres in width at its narrowest point, which is comparable to its beach width prior to the high-water years. Turkey Creek (5999) was added as a benchmark in 2022 after invasive Water Lettuce (*Pistia stratiotes*) had been found while sampling the site in 2021. It was not found during this year's sampling, nor was it observed anywhere else in the creek area travelled. We notified the Essex Region of the 2021 finding, and we will notify them of our 2022 findings as well.

Extra Sites and Data

We did not sample any extra sites in 2022.

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

The most noticeable trend observed throughout our sampling region in 2022 was the lower water levels at all sites. The wet meadow zone was present in 51 of the 57 transects sampled on Lake Huron (19 sites sampled, 57 transects in total). While over half of these (31) were large, sheltered sedge meadows that were not as affected by fluctuating water levels, the remaining 20 meadows sampled were in more exposed areas, and bore the brunt of high-water years, likely having been completely flooded until 2021. What began in 2021 as narrow, sparsely vegetated linear strips along the shoreline at only a handful of sites as the water began to recede has now expanded into wider, more defined wet meadow zones at many sites sampled, as water levels continue to lower for a second year. Thus, plant-species richness has increased as these meadows return to temporary-flooding conditions, facilitating the germination from the seed bank of many species that require these conditions. Also, areas between zones that had been "flooded out" (i.e., devoid of plants), were seen to be filling in again, eliminating some of these open-water areas. If lake levels continue to decline, we expect to see more restoration of wet-meadow plant diversity and continued revegetation of the formerly vegetation-free areas.

Data Processing

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, because field crew leaders have at least 13 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 (from fall report)

Over the last four years, Point Pelee National Park (PPNP) has been sampled as part of the CWMP to provide Parks Canada personnel with pre- and post-restoration baseline information relating to the implementation of a vegetation-removal exercise meant to reduce *Phragmites* and *Typha* encroachment and improve hydrological connectivity among several connected waterbodies. This work is also helping to identify the changes that have occurred as the result of a breach in the protective sand-spit cause by high lake levels. Sampling at PPNP is planned to continue to document post-restoration changes.

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)

No additional projects to report.

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

Team Members

- Joe Fiorino, PI, crew leader, vegetation/WQ/invert sampling (since 2016)
- Ian Smith, team leader, fish/WQ/invert sampling, GIS tech (since 2014)
- Hayley Rogers, team leader, vegetation/WQ/invert sampling (since 2017)
- Jessica Kassar, summer student field tech (since 2022)
- Aiden Muir, summer student field tech (since 2022)

Training (from fall report)

Environment and Climate Change Canada – Canadian Wildlife Service (ECCC-CWS) field crew members were trained by Joe Fiorino, Ian Smith 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 and lab for proper sample collection, data recording, GPS use, water processing, equipment calibration, and lab sample preparation and storage. A practice session at a nearby wetland and in our lab facility was conducted in June 2022 to provide hands-on training to new staff. An experienced staff member was paired with new personnel to reinforce project protocols and ensure high data quality. A mid-field-season check was conducted in mid-August. No problems were identified.

Challenges and Lessons Learned

Water Quality Samples (updated)

Water quality sampling followed the protocols dictated by the QAPP. 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. NLET reopened in September 2021 following over a year of closure due to the COVID-19 pandemic. Chlorophyll *a* samples 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 QC'ed.

Site Visit List (from fall report)

As in previous years, the number of sites originally assigned to our group (20) exceeded the capacity of the ECCC-CWS field crew, so three sites were given to SUNY-Brockport and four sites were given to University of Windsor. Two sites were not attempted, and two sites were visited but were not suitable for WQ/invert/fish sampling (explained in detail below). The following nine sites were sampled by ECCC-CWS for water quality/inverts/fish:

Site ID	Site Name
5007	Airport Creek Marsh (only water quality and inverts)
5160	Carruthers Creek Marsh
5735	Pine Point Wetland 1
5775	Presqu'ile Bay Marsh 1
5777	Presqu'ile Bay Marsh 11
5779	Presqu'ile Bay Marsh 13
5873	Sawguin Creek Marsh 5
6033	Wellers Bay Wetland 12
6073	Wilmot Rivermouth Wetland

Big Sandy Bay (5091) was not attempted, as it could not be accessed safely; there is no road into the site, walking in would require traversing a large beach and sand dunes, and there is no boat launch nearby to enter the wetland from the lake. Bath Point Wetland (5049) was a web reject due to lack of connectively to the lake.

Highland Creek Wetland (5419) could not be sampled for WQ/inverts/fish due to minimal wetland habitat and lack of a suitable sampling zone. The creek running through the site was no more than 2 m wide, 20-30 cm deep, and had little/no aquatic vegetation. This site will likely be excluded from future sampling. Similarly, Sawguin Creek Wetland 2 (5870) had no suitable vegetation zone for WQ/inverts/fish. The site was mostly mud and/or unconsolidated sediment with little aquatic vegetation. It would likely be suitable for sampling (at least for WQ/inverts and possibly fish) in a higher water-level year. Airport Creek Marsh (5007) could not be sampled for fish because the hard, rocky substrate could not be penetrated by fyke net posts.

Panel Survey Results

Fall report only. Nothing to add.

Extra Sites and Data

Fall report only. Nothing to add.

Wetland Condition Observations and Results (from fall report)

Non-native fish

Non-native fish species were caught at five of the eight sites that were sampled for fish. Round Gobies (*Neogobius melanostomus*) were caught at Carruthers Creek (5160; 4 individuals), Pine Point 1 (5735; 3 individuals), Presqu'ile 1 (5775; 4 individuals), Presqu'ile 13 (5779; 1 individual), and Sawguin Creek 5 (5873; 7 individuals). One Alewife (*Alosa pseudoharengus*) was caught at Pine Point 1 (5735). No Common Carp were captured this year.

Reptiles

Eastern Snapping Turtles (*Chelydra serpentina*) were caught at Carruthers Creek (5160; 1 individual) and Wilmot Rivermouth (6073; 1 individual). Painted Turtles (*Chrysemys picta*) were caught at Pine Point 1 (5735; 2 individuals), Presqu'ile 1 (5775; 3 individuals), Presqu'ile 11 (5777; 2 individuals), Presqu'ile 13 (5779; 2 individuals), Sawguin Creek 5 (5873; 1 individual), and Wellers Bay 12 (6033; 1 individual).

Data Processing

All water quality, fish, and invert data have been entered and QC'ed. Geospatial data were mapped in GIS to verify that waypoints were recorded correctly.

Mid-season QC Check Findings

No difficulties or anomalies were observed during mid-season 2022 checks.

Audit and QC Report and Findings

All data entry has been QC'ed by a team member with multiple years of experience working with the data entry system. QC issues identified in the Data Verification Interface and past point-matching issues are currently being addressed.

Additional Funding and Projects (updated)

In 2021 and 2022, ECCC-CWS received funding from the International Joint Commission 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 data, and ultimately identified six potential bird-based indicators for consideration by the IJC. This work was published in the Journal of Great Lakes Research in early 2023. Work to further improve these indicators is ongoing, and we are also currently investigating the use of anuran-based indicators.

Other Collaboration Activities

ECCC-CWS is funding a project on trends in marsh bird populations in collaboration with Birds Canada and CWMP PIs. Birds Canada will utilize contemporary statistical techniques to assess trends in marsh bird populations in the Great Lakes basin. The primary source of bird data will be the Great Lakes Coastal Wetland Monitoring Program (including data from 2011 to 2021). Marsh bird species considered should include, but are not limited to American Bittern, American Coot, Black Tern, Common Gallinule, Forrester's Tern, Least Bittern, Marsh Wren, Mute Swan, Pied-billed Grebe, Sandhill Crane, Sora, Swamp Sparrow, Trumpeter Swan, Virginia Rail, and Wilson's Snipe.

Other Data Requests

ECCC-CWS received a request from Fisheries and Oceans Canada to share CWMP macrophyte quadrat data (species, coverage) and water quality data (temp, ph, DO, turb, cond) from all Lake Erie coastal wetlands and select Lake Ontario coastal wetlands (those that are generally closed to the lake). These data are being used by DFO's Science Sector to analyze wetland conditions that support the persistence of Lake Chubsucker (a federal SAR) within Canada. The results of these analyses will be used to develop scientific advice about the response of Lake Chubsucker to water-level drawdown and other habitat manipulations, and will be used to inform an upcoming Government of Canada Canadian Science Advisory Secretariat (CSAS) peer review meeting. The main documents stemming from the meeting will be a Government of Canada Research Document, which describes the analysis that was undertaken using the requested data, as well as a Science Advisory Report, which is a short summary of the Research Document that provides a high-level summary of key findings. These documents are not primary publications, but are published on the DFO CSAS website and are publicly available. In the event that follow-up primary publications are developed, they would reach out to determine if CWMP PIs are interested in collaborating on those publications. ECCC-CWS received support from the relevant PIs to share these data and a formal data request on letterhead was provided to the project leads. This request was entered in the Data Request Tracking document.

In November 2022, the bird/anuran team received a request to make a dataset used for a manuscript submitted to Ecosphere available through an online data repository (the dataset included 194 wetlands sampled through the CWMP in 2016 and 2017). This request was granted by the project leads and was entered in the Data Request Tracking document.

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 (since 2016)
- Ian Smith, team leader, fish/WQ/invert sampling, GIS tech (since 2014)
- Hayley Rogers, team leader, vegetation/WQ/invert sampling (since 2017)
- Jessica Kassar, summer student field tech (since 2022)
- Aiden Muir, summer student field tech (since 2022)

Training (from fall report)

Environment and Climate Change Canada – Canadian Wildlife Service (ECCC-CWS) field crew members were trained by Joe Fiorino, Ian Smith 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. A practice session at a nearby wetland and in our lab facility was conducted in June 2022 to provide hands-on training to new staff. An experienced staff member was paired with new personnel to reinforce project protocols and ensure high data quality. A mid-field-season check was conducted in mid-August. No problems were identified.

Challenges and Lessons Learned (from fall report)

Water levels

Lake Ontario water levels in August 2022 were roughly 10 cm lower than in August 2021, and 30 cm lower than in 2020. At sites such as Airport Creek Marsh (5007) and Wellers Bay Wetland 12 (6033), dense vegetation cover and low water levels in channels made paddling very difficult, occasionally limiting accessibility to certain areas.

Site Visit List (from fall report)

As in previous years, the number of 2022 sites originally assigned to our group (20) exceeded the capacity of the ECCC-CWS field crew, so three sites were given to SUNY-Brockport and four sites were given to University of Windsor. Two sites were not attempted (details are below). The following 11 sites were sampled by ECCC-CWS for vegetation:

Site ID	Site Name
5007	Airport Creek Marsh
5160	Carruthers Creek Marsh
5419	Highland Creek Wetland
5735	Pine Point Wetland 1
5775	Presqu'ile Bay Marsh 1
5777	Presqu'ile Bay Marsh 11
5779	Presqu'ile Bay Marsh 13
5870	Sawguin Creek Marsh 2
5873	Sawguin Creek Marsh 5
6033	Wellers Bay Wetland 12

6073	Wilmot Rivermouth Wetland

Big Sandy Bay (5091) was not attempted, as it could not be accessed safely; there is no road into the site, walking in would require traversing a large beach and sand dunes, and there is no boat launch nearby to enter the wetland from the lake. Bath Point Wetland (5049) was a web reject due to lack of connectively to the lake.

Panel Survey Results

Fall report only. Nothing to add.

Extra Sites and Data

Nothing to add. No benchmark sites were sampled and no extra data were collected.

Wetland Condition Observations and Results (from fall report)

Similar to 2021, with another year of relatively low water levels, the vegetation crew noticed more meadow species mixed with *Typha* sp. in emergent portions of the transects. There were no new invasives or notable rare species to report.

Data Processing

All vegetation data have been entered and QC'ed. 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

No difficulties or anomalies were observed during 2022 mid-season checks.

Audit and QC Report and Findings (updated)

All data entry has been QC'ed by a team member with multiple years of experience working with the data entry system. QC issues identified in the Data Verification Interface and past point-matching issues are currently being addressed.

Additional Funding and Projects

In 2021 and 2022, ECCC-CWS received funding from the International Joint Commission 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 data, and ultimately identified six potential bird-based indicators for consideration by the IJC. This work was published in the Journal of Great Lakes Research in early 2023. Work to further improve these indicators is ongoing, and we are also currently investigating the use of anuran-based indicators.

ECCC-CWS is also currently working on developing a plant-based indicator for each of the Great Lakes using the Index of Ecological Condition method developed by Bob Howe.

Other Collaboration Activities

ECCC-CWS is funding a project on trends in marsh bird populations in collaboration with Birds Canada and CWMP PIs. Birds Canada will utilize contemporary statistical techniques to assess trends in marsh bird populations in the Great Lakes basin. The primary source of bird data will be the Great Lakes Coastal Wetland Monitoring Program (including data from 2011 to 2021). Marsh bird species considered should include, but are not limited to American Bittern, American Coot, Black Tern, Common Gallinule, Forrester's Tern, Least Bittern, Marsh Wren, Mute Swan, Pied-billed Grebe, Sandhill Crane, Sora, Swamp Sparrow, Trumpeter Swan, Virginia Rail, and Wilson's Snipe.

Other Data Requests

ECCC-CWS received a request from Fisheries and Oceans Canada to share CWMP macrophyte quadrat data (species, coverage) and water quality data (temp, ph, DO, turb, cond) from all Lake Erie coastal wetlands and select Lake Ontario coastal wetlands (those that are generally closed to the lake). These data are being used by DFO's Science Sector to analyze wetland conditions that support the persistence of Lake Chubsucker (a federal SAR) within Canada. The results of these analyses will be used to develop scientific advice about the response of Lake Chubsucker to water-level drawdown and other habitat manipulations, and will be used to inform an upcoming Government of Canada Canadian Science Advisory Secretariat (CSAS) peer review meeting. The main documents stemming from the meeting will be a Government of Canada Research Document, which describes the analysis that was undertaken using the requested data, as well as a Science Advisory Report, which is a short summary of the Research Document that provides a high-level summary of key findings. These documents are not primary publications, but are published on the DFO CSAS website and are publicly available. In the event that follow-up primary publications are developed, they would reach out to determine if CWMP PIs are interested in collaborating on those publications. ECCC-CWS received support from the relevant PIs to share these data and a formal data request on letterhead was provided to the project leads. This request was entered in the Data Request Tracking document.

In November 2022, the bird/anuran team received a request to make a dataset used for a manuscript submitted to Ecosphere available through an online data repository (the dataset included 194 wetlands sampled through the CWMP in 2016 and 2017). This request was granted by the project leads and was entered in the Data Request Tracking document.

Related Student Research

None at this time.

EASTERN BASIN BIRD AND ANURAN TEAM, SUNY BROCKPORT

Team Members

- Dr. Kathryn Amatangelo, PI (since 2014)
- Gregory Lawrence, acting bird and anuran PI, project manager (2011-14, since 2018)
- Ray Marszalek, graduate research assistant and bird and anuran team lead (since 2021)
- Robert Buckert, undergraduate research assistant (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 7, 2022 at SUNY Brockport campus and at site 15-Yanty Marsh. Bird training was held on May 23, 2022 at SUNY Brockport campus and site 15-Yanty Marsh. Both technicians were trained on July 21, 2022 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>

One field technician, R. Marszalek, will return for the 2023 field season and has already successfully passed the bird and anuran identification and certification tests in 2021. Dr. Kristen Malone will join the bird and anuran team at SUNY Brockport as the bird and anuran principal investigator in Spring 2023 and will assist in training, data review, and field work. She, along with project manager Gregory Lawrence, will train a second technician in Spring 2023 in accordance with 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 2022 allowing crews to easily travel out of state to sites in Ohio and Pennsylvania. Further, travel restrictions across the United States-Canada border were loosened and crews were able to cross the border and sample sites in Ontario for the first time since 2019.

Lake Ontario water levels returned from record highs in 2017 and 2019 to about average in summer 2022 reducing site access and sampling issues associated with extraordinarily high and low water levels.

Site Visit List

SUNY Brockport bird and anuran teams plan on sampling a total of 27 sites across the US Eastern Basin including 17 panel, four panel pre-sample, three panel re-sample, and three benchmark sites in 2023. Site 123, Little Sandy Creek, Site 7021, South Colwell, and site 1830, Buckhorn Island Wetland, are the three panel re-sample sites, while site 28, Salmon Creek, site 116, Ramona Beach Marsh, site 5635, Mill Point Wetland, and site 5008, Amherst Bar Wetland 1 are the four panel pre-sample sites. Cranberry Pond (site 50) is a panel site for 2023 but will be sampled as a benchmark site for water quality in 2023 as part of post-restoration sampling for a NFWF/Audubon funded project within the Rochester Embayment AOC. Yanty Marsh (site 15), will be sampled again as a benchmark site in 2023 as part of pre-restoration monitoring for a proposed USEPA-funded restoration project run by New York State Office of Parks and Historic Preservation. Lastly, Floodwood Pond (site 7024) will be sampled as a benchmark site in 2023 as part of pre-restoration monitoring for a proposed Audubon/Ducks Unlimited restoration project. Further, this site has high IEC scores compared to most sites in the US Eastern Basin and sampling for all taxa will help sample sites at the extreme ends of the site quality gradient.

Panel Survey Results (from fall report)

SUNY Brockport crews sampled anurans starting on April 7, 2022 and finished sampling on July 10, 2022. Crews detected seven anuran species, including spring peeper (*Pseudacris crucifer*), gray tree frog (*Hyla versicolor*), northern leopard frog (*Lithobates pipiens*), green frog (*Lithobates clamitans*), bullfrog (*Lithobates catesbeiana*), Fowler's toad (*Anaxyrus fowleri*) 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 May 20, 2022 and finished sampling on July 10, 2022. Crews detected three species listed as endangered, threatened, and special concern in New York State including Peregrine Falcon (*Falco peregrinus*), listed as endangered, at site 7053-Irondequoit Bay Wetland. Crews detected Least Bittern (*Ixobrychus exilis*), listed as a threatened species in New York State, at site 122-North Pond Area Wetland, and Bald Eagle (*Haliaeetus leucocephalus*), also listed as a threatened species in New York State, at sites 122-North Pond Area Wetland and 7052-Braddock Bay. Crews detected Common Loon (*Gavia immer*), listed as a species of special concern in New York State, at site 7052-Braddock Bay, 133-Stony Creek Marsh, and 167-Chaumont River Mouth Wetland, and Common Nighthawk (*Chordeiles minor*), also listed as a species of special concern in New York State, at site 11-Oak Orchard Wetland, and 7052-Braddock Bay. Crews failed to detect Black Tern (*Chlidonias niger*), listed as an endangered species in New York State, at any sites during summer 2022, despite this species being present during sampling at many of the same sites in past years.

Extra Sites and Data (from fall report)

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. Site 5-Eighteenmile Creek Wetland was 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. Site 15-Yanty Marsh was sampled as a non-panel benchmark site to provide pre-restoration data for an upcoming USEPA-funded project supported by New York State Office of Parks and Historic Preservation. Crews detected four species listed as special concern in New York State including American Bittern (*Botaurus lentiginosus*) at site 15-Yanty Marsh, Osprey (*Pandion haliaetus*) at site 15-Yanty Marsh, Cooper's Hawk (*Accipiter cooperii*) at site 50-Cranberry Pond, and Red-headed Woodpecker (*Melanerpes erythrocephalus*) at site 15-Yanty Marsh.

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 and Erie were about average to slightly below average in summer 2022, resulting in little water near the edges of the wetland where bird and anuran surveys occur. This may have impacted detectability of secretive marsh birds and focal species that require some interspersion of water and vegetation. We did not detect any other significant disturbances across the sites in the US Eastern basin that would affect 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 June 12, 2022 at sites 7053, Irondequoit Bay Wetland, and 53-Little Pond Wetland. Both crew members (R. Marszalek and R. Buckert) successfully met mid-season check performance criteria described in the project QAPP and had no issues requiring corrective action.

Audit and QC Report and Findings

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

Additional Funding and Projects

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

Other Collaboration Activities (from fall report)

Site 7052-Braddock Bay, was sampled for birds and anurans as a panel site and supplemented 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.

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

Further, SUNY Brockport crews shared state listed bird and anuran species found at sites 1830-Buckhorn Island Wetland, 8-Golden Hill State Park Wetland, and 15-Yanty Marsh with colleagues at the New York State Office of Parks and Historic Preservation. Further, crews shared observations from sites 1844-Presque Isle Bay Wetland and 1941-Thompson Bay Area Wetland with colleagues at Pennsylvania Department of Conservation and Natural Resources.

Figure 37. Eastern Kingbird (*Tyrannus tyrannus*). Photo credit: Ray Marszalek.

Other Data Requests

None to report.

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

Team Members

- Dr. Kathryn Amatangelo, PI (since 2014)
- Dr. Matthew Altenritter, PI (since 2020)
- Dr. Michael Chislock, PI (since 2018)
- Gregory Lawrence, project manager (2011-14, since 2018)
- Madelynn Edwards, invertebrate laboratory technician (since 2019)
- Jakob Scholeno, graduate research assistant (since 2022)
- Dillon Vandemortel, graduate research assistant (new 2023)

Training

All five field technicians 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 21-24, 2022 at the SUNY Brockport campus, Glenwood Lake reservoir in Medina, NY for boat training, and at site 16-Sandy Harbor Wetland for field training. Lastly, all five field technicians were trained on August 12, 2022 on data entry and QC checks in the database. All five field technicians were successfully trained and met pre-season and mid-season training performance criteria described in the project QAPP.

<u>Update</u>

Two new undergraduate students will join Dillon Vandemortel, new graduate research assistant, and Jakob Scholeno, returning graduate research assistant, to conduct fish, aquatic macroinvertebrate, and water quality sampling during the 2023 field season. They will be trained by PIs Dr. Kathryn Amatangelo, Dr. Michael Chislock, and Dr. Matthew Altenritter, and project manager Gregory Lawrence 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 2022 allowing crews to easily travel out of state to sites in Pennsylvania. Further, travel restrictions across the United States-Canada border were loosened and crews were able to cross the border and sample sites in Ontario for the first time since 2019.

Lake Ontario water levels returned from record highs in 2017 and 2019 to about average in summer 2022 reducing site access and sampling issues associated with extraordinarily high and low water levels. Most sites had ideal sampling conditions for setting fyke nets in multiple vegetation zones.

Site Visit List

The SUNY Brockport fish, invertebrate, and water quality team plans on sampling a total of 18 sites across the US Eastern Basin including ten regular panel sites, three panel re-sample, two panel pre-sample, and three non-panel (benchmark) sites in 2023. Site 123, Little Sandy Creek, Site 7021, South Colwell, and site 1830, Buckhorn Island Wetland, are the three panel re-sample sites, while site 28, Salmon Creek and site 116, Ramona Beach Marsh are the two panel pre-sample sites. Cranberry Pond (site 50) is a panel site for 2023 but will be sampled as a benchmark site for water quality in 2023 as part of post-restoration sampling for a NFWF/Audubon funded project within the Rochester Embayment AOC. Yanty Marsh (site 15), will be sampled again as a benchmark site in 2023 as part of pre-restoration monitoring for a proposed USEPA-funded restoration project run by New York State Office of Parks and Historic Preservation. Lastly, Floodwood Pond (site 7024) will be sampled as a benchmark site in 2023 as part of pre-restoration monitoring for a proposed Audubon/Ducks Unlimited restoration project. Further, this site has high IEC scores compared to most sites in the US Eastern Basin and sampling for all taxa will help sample sites at the extreme ends of the site quality gradient.

Panel Survey Results (from fall report)

SUNY Brockport crews sampled fish, water quality, and invertebrates at panel sites starting on June 27, 2022 at site 7053, Irondequoit Bay Wetland, and finished on August 3, 2022 at site 1941, Thompson Bay Area Wetland

Notable fish included spotted gar (*Lepisosteus oculatus*) at site 1844-Presque Isle Bay Wetland, and longnose gar (*Lepisosteus osseus*) at sites 119-South Pond Wetland and 164-Guffin Bay Wetland. Invasive rudd (*Scardinius erythrophthalmus*) were caught at sites 1830-Buckhorn

Island Wetland and 7053-Irondequoit Bay Wetland. Invasive freshwater tubenose goby (*Proterorhinus semilunaris*) was caught at site 1941-Thompson Bay Wetland.

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 sites 119-South Pond Wetland, 123-Little Sandy Creek Wetland, 1844-Presque Isle Bay Wetland, and 1941-Thompson Bay Area Wetland. Crews caught map turtles (*Graptemys geographica*) at sites 167-Chaumont River Mouth Wetland, and 1941-Thompson Bay Wetland. Lastly, crews caught a spiny softshell turtle (*Apalone spinifera*), a species very rarely caught during sampling, at site 1844-Presque Isle Bay Wetland.

Figure 38. Spiny softshell turtle (Apalone spinifera) at site 1844, Presque Isle Bay Wetland.

Extra Sites and Data (from fall report)

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 5-Eighteenmile Creek Wetland, 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 very low quality site and had never been sampled for fish, invertebrates, plants, and water quality due to exceeding site capacity. Site 5-Eighteenmile Creek Wetland was added as a benchmark in 2022 as part of an increased effort to better sample sites with extremely good or poor environmental conditions, as well as to better assess the overall site condition by sampling all taxa. Crews caught ten taxa at this site including round goby (*Neogobius melanostomus*), an invasive species in New York State. Site 15-Yanty Marsh was sampled as a non-panel benchmark site to provide pre-restoration data for an upcoming USEPA-funded project supported by New York State Office of Parks and Historic Preservation. The only notable species caught at site 15-Yanty Marsh was rudd, an invasive species in New York State.

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

Wetland Condition Observations and Results (from fall report)

Water levels on Lake Ontario were about average in summer 2022 resulting in good access at almost all sites and boat launches. Water levels were adequate at all sites for setting fyke nets in multiple vegetation zones. Further, lower lake levels later in the summer in some 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. Low levels prevented sampling at site 5559-Lower Napanee River as the entire open area at the site was a mudflat.

Data Processing

SUNY Brockport crews have completed 100% data entry and QC checks for fish, field water quality, and field invertebrate data. 100% unknown fish were identified and entered in the database. 100% laboratory water quality analyses, data entry, and QC checks were completed. 100% laboratory invertebrate processing and identification has been completed and date are 100% entered and 100% QC checks are completed.

Mid-season QC Check Findings (from fall report)

The water quality and invertebrate mid-season QC check was completed on July 15, 2022 at site 7021-South Colwell by Dr. Michael Chislock and project manager Gregory Lawrence. The three crew members (C. Diguardi, J. Scholeno, and M. Suflita) 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 15, 2022 at site 7021-South Colwell, by Dr. Matthew Altenritter. Both crew members (J. Ludwig and A. DiMariano) successfully met mid-season performance criteria described in the project QAPP and had no issues requiring corrective action.

Audit and QC Report and Findings

SUNY Brockport crews have completed 100% data entry QC checks for fish, field water quality, and field invertebrate data. 100% laboratory water quality analyses, data entry, and QC checks were completed. 100% laboratory invertebrate processing and identification has been completed and data are 100% entered and 100% QC checks are completed.

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 panel site and supplemented 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. SUNY Brockport 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 to assist in further management, monitoring, and/or eradication.

SUNY Brockport shared state listed fish species found at sites 1830-Buckhorn Island Wetland, 8-Golden Hill State Park Wetland, and 15-Yanty Marsh with colleagues at the New York State

Office of Parks and Historic Preservation. Further, crews shared species lists from sites 1844-Presque Isle Bay Wetland and 1941-Thompson Bay Area Wetland with colleagues at Pennsylvania Department of Conservation and Natural Resources.

Other Data Requests

None to report.

EASTERN BASIN VEGETATION TEAM, SUNY BROCKPORT

Team Members

- Dr. Kathryn Amatangelo, PI (since 2014)
- Dr. Rachel Schultz, PI (since 2019)
- Gregory Lawrence, project manager (2011-14, since 2018)
- Kevin Killigrew, graduate research assistant and 2022 field crew leader (since 2019)

Training

Both field technicians (K. Killigrew and B. Schmidt) 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 technicians were trained by Dr. Rachel Schultz on plant identification and sample preservation and storage. All training took place June 21-24, 2022 at the SUNY Brockport campus, Glenwood Lake reservoir in Medina, NY for boat training, and at site 16-Sandy Harbor Wetland, for field training. Lastly, both field technicians were trained on August 10, 2022 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>

A new graduate research assistant and undergraduate research assistant will join the crew in 2023 and be trained by PIs Dr. Rachel Schultz and Dr. Kathryn Amatangelo and project manager Gregory Lawrence as per performance criteria described in the project QAPP.

Loosened restrictions regarding the COVID-19 pandemic greatly reduced travel restrictions and logistical issues in 2022 allowing crews to easily travel out of state to sites in Pennsylvania. Further, travel restrictions across the United States-Canada border were loosened and crews were able to cross the border and sample sites in Ontario for the first time since 2019.

Lake Ontario water levels returned from record highs in 2017 and 2019 to about average in summer 2022, reducing site access and sampling issues associated with extraordinarily high and low water levels. Most sites were readily accessible for crews to sample vegetation.

Site Visit List (mostly from fall report)

The SUNY Brockport vegetation team plans on sampling a total of 18 sites across the US Eastern Basin including ten regular panel sites, three panel re-sample, two panel pre-sample, and three non-panel (benchmark) sites in 2023. Site 123, Little Sandy Creek, Site 7021, South Colwell, and site 1830, Buckhorn Island Wetland, are the three panel re-sample sites, while site 28, Salmon Creek and site 116, Ramona Beach Marsh are the two panel pre-sample sites. Cranberry Pond (site 50) is a panel site for 2023 but will be sampled as a benchmark site for water quality in 2023 as part of post-restoration sampling for a NFWF/Audubon funded project within the Rochester Embayment AOC. Yanty Marsh (site 15), will be sampled again as a benchmark site in 2023 as part of pre-restoration monitoring for a proposed USEPA-funded restoration project run by New York State Office of Parks and Historic Preservation. Lastly, Floodwood Pond (site 7024) will be sampled as a benchmark site in 2023 as part of pre-restoration monitoring for a proposed Audubon/Ducks Unlimited restoration project. Further, this site has high IEC scores compared to most sites in the US Eastern Basin and sampling for all taxa will help sample sites at the extreme ends of the site quality gradient.

Panel Survey Results (from fall report)

SUNY Brockport crews sampled vegetation at panel sites starting on June 27, 2022 at site 7053-Irondequoit Bay Wetland and finished on August 3, 2022 at site 1941-Thompson Bay Area Wetland. Crews found southern blue flag (*Iris virginica*), listed as endangered in New York State, at site 16-Sandy Harbor Wetland. Crews also detected native *Phragmites americanus*, listed as a rare species in New York State, at site 119-South Pond Wetland #1, 199-Mud Bay Marsh 2, and across the border in Ontario, Canada at site 5407-Hay Bay Marsh 8. Crews sampled a unique intact coastal fen at Site 119-South Pond Wetland #1 with multiple unique wetland plants including *Drosera rotundifolia*, *Pogonia ophioglossoides*, *Menyanthes trifoliata*, and *Vaccinium macrocarpon*. Site 199-Mud Bay Marsh 2 had vast meadow marsh sections with unique species such as *Carex stricta*, *Spiraea alba*, *Carex aurea*, *Sium suave*, and *Hypericum ellipticum*. Crews sampled more meadow marsh zones than is typical for the Lake Ontario crew, potentially due to changes in lake level regulation.

Extra Sites and Data (from fall report)

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 5-Eighteenmile Creek Wetland, was sampled for vegetation as a non-panel benchmark site as bird and anuran index of ecological condition values indicated it was a low quality site and it had never been sampled for fish, invertebrates, plants, and water quality due to exceeding site capacity. Site 5-Eighteenmile Creek Wetland, was added as a benchmark to include sites with extremely good or poor environmental condition. This site had very narrow vegetation zones and anecdotally poor vegetation quality compared to others. Site 15-Yanty Marsh was sampled as a non-panel benchmark site to provide pre-restoration data for an upcoming USEPA-funded project supported by New York State Office of Parks and Historic Preservation.

Data collected at these sites will help inform stakeholders, partners, and land managers on pre- and 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 about average in summer 2022 resulting in good access at almost all sites and boat launches. Crews noted an increase in dead *Typha* cover and decrease in live *Typha* cover in sedge-grass meadow zones in summer 2022, similar to that in 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 14, 2022 at site 7021-South Colwell by Dr. Rachel Schultz. Both crew members (K. Killigrew and B. Schmidt) 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. Plant crew PI Dr. Rachel Schultz conducted a data audit and found no issues with plant IDs from 2022 data collection and sampling. If ID issues are found during a data audit, targeted training sessions and workshops in the lab and in the field would be used to better train crew members on difficult identifications and/or techniques.

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 panel site and supplemented 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 Finger Lakes and St. Lawrence-Eastern Lake Ontario Partnerships for Regional Invasive Species Management by reporting invasive species, such as water chestnut (*Trapa natans*), detected at each wetland to assist in further management, monitoring, and/or eradication.

SUNY Brockport shared species lists found at sites 1830-Buckhorn Island Wetland, 8-Golden Hill State Park Wetland, and 15-Yanty Marsh with colleagues at the New York State Office of Parks and Historic Preservation. We shared species lists from sites 1844-Presque Isle Bay Wetland and 1941-Thompson Bay Area Wetland with colleagues at Pennsylvania Department of Conservation and Natural Resources.

Other Data Requests

None to report

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. One 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. The QAPP was updated in spring of 2023 (signed by all PIs) to reflect the re-creation of the Site Management System by Limnotech to be housed at Central Michigan University.

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

This winter we, in collaboration with GDIT, implemented a data verification protocol that is being 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 for which some other number of transects than three was 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 May 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 39). 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 based on assessment by lead PIs.

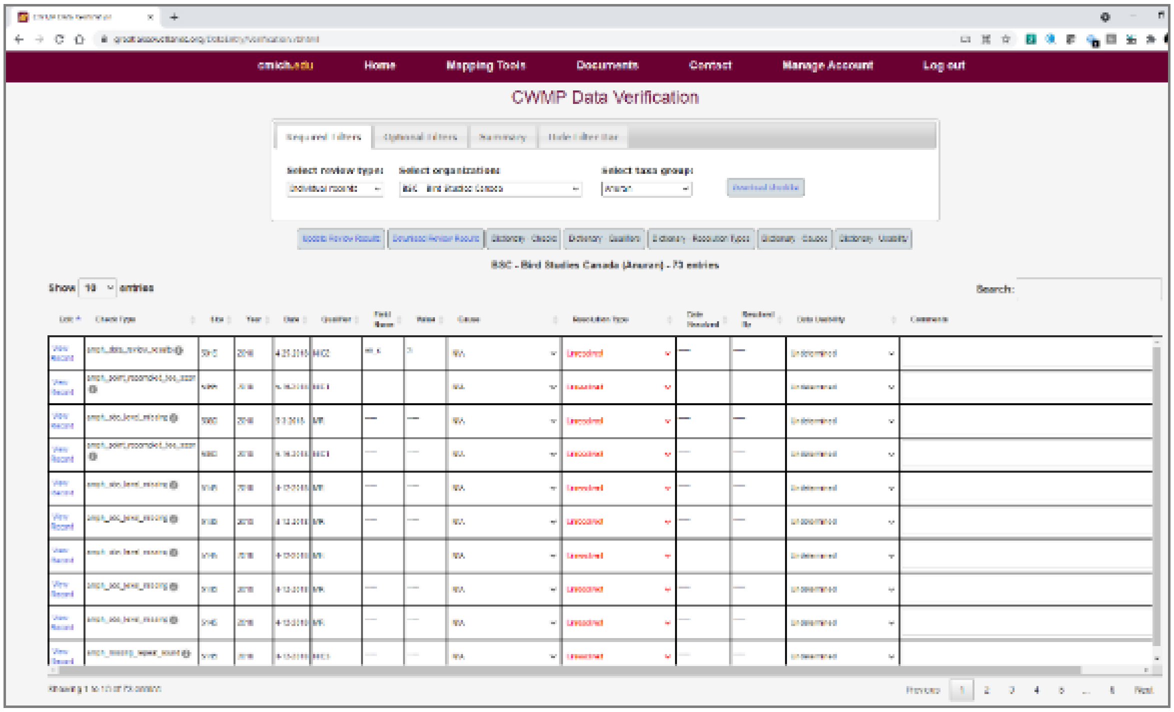

Figure 39. CWMP data verification user interface.

The CWMP lead PIs reviewed the verification criteria information provided by GLNPO and GDIT, as well as the data verification tool described above. The tool was introduced and training provided to all taxonomic groups in the fall of 2022. This first round of data verification covers years 2016 – 2021. Over the winter, teams reviewed hundreds of items in the database that failed these data verification checks. A few items showed that checks need to be re-written (for example, fish lengths for young-of-year cutoffs), but most checks worked well and flagged things that needing correction, updating, or decisions about whether or not to quarantine the data. To data, teams have resolved 50-90% of the issues found by the checks and will work on finishing this work in the fall.

EXAMPLE WATER QUALITY QC INFORMATION

Laboratory Quality Assurances

Water quality analyses from 2022 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 2022 have passed the criteria shown below (Table 17) or were excluded from the database.

Table 16. 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 (not updated for 2022 due to late WQ data QC)

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 17. 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 enters its thirteenth year (third year of round 3 sampling). Nearly all program members virtually attended an all-hands Zoom program organizational meeting in March of 2023. 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, how we could keep diverse teams safe, data validation and correction, manuscripts, 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 despite a global pandemic. 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 – 2023)

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. Additional sampling and analysis is scheduled for 2023. Dr. Matt Cooper led this project with students from Muskegon Community College.

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 protocols.

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 Modeling 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 nonbreeding portion of their life cycle. Data are currently being analyzed by researchers at the Natural Resources Research Institute in Duluth MN.

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

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

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

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

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

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

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

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

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

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

Chlorophyll-*a* Modeling: The UND team, in collaboration with Northland College, CMU, and others, is investigating the drivers that influence water column chlorophyll-*a* in coastal wetlands. Our hypothesis is that chlorophyll-*a* will be related to nutrient status of wetlands and degree of development of adjoining land. Along with CWM water data, we are utilizing GIS land use and connectivity data. Specifically, we seek to answer the following questions: (1) What variables best predict chlorophyll-*a* in coastal wetlands across the entire Great Lakes basin? (2)

How do these variables change across each basin (i.e., Lake Michigan, Lake Erie, Lake Ontario, Lake Superior, Lake Huron)? (3) Are there differences in predictor variables across sub-basins (e.g., Lake Erie North vs. Lake Erie South)? (4) Does wetland type (lacustrine, riverine, or barrier) change chlorophyll-*a* predictors? (5) How do other potential variables, such as vegetation zone type or year, change chlorophyll-*a* predictors?

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

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

Hybridizing fish: In 2013 the NRRI field crew encountered gar around the Green Bay area of Lake Michigan which exhibited mixed morphological traits of shortnose and longnose species. At that time, John Lyons at the Wisconsin Department of Natural Resources was working on a project to confirm hybrid individuals in the Fox River watershed (which drains into Green Bay, WI). Josh Dumke at NRRI contributed photos of gar captured in Green Bay during Coastal Wetland Monitoring fish surveys to John Lyons, and those contributions were acknowledged in a recently-published article: (Lyons, J., and J.T. Sipiorski. 2020. Possible large-scale hybridization and introgression between Longnose Gar (Lepisosteous osseus) and Shortnose Gar (Lepisosteous platostomus) in the Fox River drainage, Wisconsin. *American Midland Naturalist*, 183:105-115). In 2014 and 2015 Coastal Wetland Monitoring fish teams collected gar fin clips across the entire Great Lakes basin for a much more comprehensive look at species distributions and hybridization, but sample processing and analysis of those stored samples is dependent upon securing additional funds.

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

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

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

SUPPORT FOR UN-AFFILIATED PROJECTS

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

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

Wetland Floristic Quality in the St. Louis River Estuary: With support from WI Sea Grant 2014-2017, vegetation PI N. Danz has integrated vegetation surveys from the CWM project with data from 14 other recent projects in the estuary. A new relational database was created that is being used to assess spatial and temporal patterns in floristic quality and to develop materials to inform and monitor wetland restorations in this AOC.

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

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

REQUESTS FOR ASSISTANCE COLLECTING MONITORING DATA

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

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

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

Other groups have requested help sampling sites that are believed to be in very good condition (at least for their geographic location), or are among the last examples of their kind, and are on lists to be protected. These requests have come from The Nature Conservancy for Green Bay sites (they are developing a regional conservation strategy and attempting to protect the best remaining sites); the St. Louis River AOC delisting committee to provide target data for restoration work (i.e., what should a restored site "look" like); and the Wisconsin DNR Natural Heritage Inventory has requested assistance in looking for rare, endangered, and threatened species and habitats in all of the coastal wetlands along Wisconsin's Lake Superior coastline. Southern Lake Michigan wetlands have mostly been lost, and only three remain that are truly coastal wetlands. CWM PIs are working with Illinois agencies and conservation groups to collaboratively and thoroughly sample one of these sites, and the results will be used to help manage all 3 sites.

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

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

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

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

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

STUDENT RESEARCH SUPPORT

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

- Using advanced morphometrics to improve identification of Sphaeriidae (fingernail clams) of the Great lakes as informed by DNA analyses (University of Minnesota Duluth; other field crews providing specimens).
- Importance of coastal wetlands to offshore fishes of the Great Lakes: Dietary support and habitat utilization (Central Michigan University; with additional funding from several small University grants and the US Fish and Wildlife Service).

- Spatial variation in macroinvertebrate communities within two emergent plant zones in Great Lakes coastal wetlands (Central Michigan University; with additional funding from CMU).
- Invertebrate co-occurrence patterns in coastal wetlands of the Great Lakes: Community assembly rules (Central Michigan University; additional funding from CMU)
- Functional indicators of Great Lakes coastal wetland health (University of Notre Dame; additional funding by Illinois-Indiana Sea Grant).
- Evaluating environmental DNA detection alongside standard fish sampling in Great Lakes coastal wetland monitoring (University of Notre Dame; additional funding by Illinois-Indiana Sea Grant).
- Nutrient-limitation in Great Lakes coastal wetlands (University of Notre Dame; additional funding by the UND College of Science).
- A summary of snapping turtle (*Chelydra serpentina*) by-catch records in Lake Ontario coastal wetlands (with additional funding by University of Toronto).
- Evaluating a zoobenthic indicator of Great Lakes wetland condition (with additional funding from University of Windsor).
- Testing and comparing the diagnostic value of three fish community indicators of Great Lakes wetland condition (with additional funding from GLRI GLIC: GLEI II and University of Windsor).
- Quantifying Aquatic Invasion Patterns Through Space and Time: A Relational Analysis of the Laurentian Great Lakes (University of Minnesota Duluth; with additional funding and data from USEPA)
- Novel Diagnostics for Biotransport of Aquatic Environmental Contaminants (University of Notre Dame, with additional funding from Advanced Diagnostics & Therapeutics program)
- Conservation of Common Terns in the Great Lakes Region (University of Minnesota; with additional funding from USFWS, MNDNR, and multiple smaller internal and external grants).
- Distribution of yellow perch in Great Lakes coastal wetlands (Grand Valley State University; with additional funding from GVSU).
- Variation in aquatic invertebrate assemblages in coastal wetland wet meadow zones of Lake Huron, of the Laurentian Great Lakes (University of Windsor; with additional funding from the University of Windsor).
- Influence of water level fluctuations and diel variation in dissolved oxygen concentrations on fish habitat use in Great Lakes coastal wetlands (University of Windsor; with additional funding from the University of Windsor).

- Bird community response to changes in wetland extent and lake level in Great Lakes coastal wetlands (University of Wisconsin-Green Bay with additional funding from Bird Studies Canada)
- Inferential measures for a quantitative ecological indicator of ecosystem health (University of Wisconsin-Green Bay)
- Per- and polyfluorinated alkyl substances (PFAS) in Great Lakes food webs and sportfish (University of Notre Dame)

Undergraduate Research with Leveraged Funding:

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

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

Graduate Research without Leveraged Funding:

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

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

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

Undergraduate Research without Leveraged Funding:

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

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

Jobs Created/Retained (2020):

- Principal Investigators (partial support): 22
- Post-doctoral researchers (partial support): 4
- Total graduate students supported on project (part-time): 19
- Unpaid undergraduate internship (summer): Not possible in 2020 due to Covid-19
- Undergraduate students (paid; summer and/or part-time): 21
- Technicians, jr. scientists (summer and/or partial support): 39
- Volunteers: Could not have volunteers in 2020 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 meetings in 2021 and 2023, we conducted a formal discussion session on Diversity, Equity, and Inclusion (DEI). In 2021, we split 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. These discussion notes were compiled and organized, and then redistributed to all CWMP participants. In 2023 we focused our discussion on how to increase crew safety as field crews diversify, acknowledging that people from differing backgrounds, ethnicities, and identities may be treated differently and feel less safe. Our goal, as always, is for all field crew members to both feel and be safe. CWMP leadership will continue to monitor and encourage DEI goals for the program.

PRESENTATIONS ABOUT THE COASTAL WETLAND MONITORING PROJECT
(INCEPTION THROUGH 2023)

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.

Amatangelo, K., D. Wilcox, R. Schultz, M. Altenritter, M. Chislock, and G. Lawrence. 2021. Application of the Great Lakes Coastal Wetlands Monitoring Program to Restoration Projects in Lake Ontario Wetlands. State of Lake Ontario Conference. March 9-11, 2021, online.

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

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

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

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

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

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

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

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

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

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

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

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

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

Brady, V., D. Uzarski, T. Brown, G. Niemi, M. Cooper, R. Howe, N. Danz, D. Wilcox, D. Albert, D. Tozer, G. Grabas, C. Ruetz, L. Johnson, J. Ciborowski, J. Haynes, G. Neuderfer, T. Gehring, J. Gathman, A. Moerke, G. Lamberti, C. Normant. 2013. A Biotic Monitoring Program for

Great Lakes Coastal Wetlands. Society of Wetland Scientists annual meeting, Duluth, MN, June 2013. 25 attendees, mostly scientists, some agency personnel.

Brady, V., D. Uzarski, T. Brown, G. Niemi, M. Cooper, R. Howe, N. Danz, D. Wilcox, D. Albert, D. Tozer, G. Grabas, C. Ruetz, L. Johnson, J. Ciborowski, J. Haynes, G. Neuderfer, T. Gehring, J. Gathman, A. Moerke, G. Lamberti, C. Normant. 2013. Habitat Values Provided by Great Lakes Coastal Wetlands: based on the Great Lakes Coastal Wetland Monitoring Project. Society of Wetland Scientists annual meeting, Duluth, MN, June 2013. 20 attendees, mostly scientists.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Miranda, D.A., Zachritz, A.M., Whitehead, H.D., Peaslee, G.F., Cressman, S. R., Lamberti, G.A. PFAS Permeates Native and Introduced Salmonids from Lake Michigan, USA. Joint Aquatic Sciences Meeting, Grand Rapids, MI. May 2022.

Miranda, D.A., Zachritz, A.M., Whitehead, H.D., Peaslee, G.F., Cressman, S. R., Lamberti, G.A., A Survey of Sportfish for Per-and Polyfluoroalkyl Substances (PFAS): An Emerging Contaminant in the Great Lakes. Portage, IN, October 2022

Miranda, D.A., Zachritz, A.M., Whitehead, H.D., Peaslee, G.F., Cressman, S. R., Lamberti, G.A. "PFAS in Prey and Predator Fish from Lake Michigan", USA. SETAC North America 43 rd.

Annual Meeting. November 2022.

Miranda, D.A., Zachritz, A.M., Whitehead, H.D., Cressman, S., Klepinger, S., Peaslee, G.F. Lamberti, G.A. "Biomagnification of PFAS in Lake Michigan food web". Colleges of Science and Engineering Joint Annual Meeting, Notre Dame IN. December 9, 2022.

Miranda, D.A., PFAS in Lake Michigan Fish, Annual Great Lakes Conference, Institute of Water Research– Michigan State University MI. March 7, 2023.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Uzarski, D.G., Cooper, M.J., Brady, V., Sherman, J.J., and D.A. Wilcox. 2013. Use of a Basin Wide Great Lakes Coastal Wetland Monitoring Program to inform and Evaluate Protection and

Restoration Efforts. 56th International Conference on Great Lakes Research, West Lafayette, IN.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Zachritz, A.M, Miranda, D.A., Whitehead, H.D., Peaslee, G.F., Cressman, S. R., Lamberti, G.A. PFAS in Lake Michigan (USA) Salmonids: Implications for Human Dietary Intake. Joint Aquatic Sciences Meeting, Grand Rapids, MI. May 2022.

Zachritz, A.M., Miranda, D.A., Whitehead, H.D., Peaslee, G.F., Rand A.A., Harris K.J., Conard W.M., Cressman S.R., Lamberti, G.A. PFAS in Lake Michigan Salmonids: Ecological and Human Health Perspectives. Michigan PFAS Summit, virtual, December 2022.

PUBLICATIONS/MANUSCRIPTS (INCEPTION THROUGH 2023)

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

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

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

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

Conard et al. 2022 Maternal Offloading of Per- andPolyfluoroalkyl Substances to Eggs by Lake Michigan Salmonids. Environmental Science & Technology Letters. (in revision) https://doi.org/10.1021/acs.estlett.2c00627

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

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

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

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

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

Denomme-Brown, S.T., G.E. Fiorino, T. M. Gehring, G. J. Lawrence, D. C. Tozer, and G. P. Grabas. 2023. Marsh birds as ecological performance indicators for Lake Ontario outflow regulation. Journal of Great Lakes Research, in press.

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

Diller, S.N., A.M. Harrison, K.P. Kowalski, V.J. Brady, J.J.H. Ciborowski, M.J. Cooper, J.D. Dumke, J.P. Gathman, C.R. Ruetz III, D.G. Uzarski, D.A. Wilcox, J.S. Schaeffer. 2022. Influences of seasonality and habitat quality on Great Lakes coastal wetland fish community composition and diets. Wetlands Ecology & Management. DOI: 10.1007/s11273-022-09862-8

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

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

Dybiec, J.M., D.A. Albert, N.P. Danz, D.A. Wilcox, and D.G. Uzarski. 2020. Development of a preliminary vegetation-based indicator of ecosystem health for coastal wetlands of the Laurentian Great Lakes. *Ecological Indicators*. 119: 106768.

Elliott, 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, D.C. Tozer, L.D. Igl LD. 2023. Application of habitat association models across regions: useful explanatory power retained in wetland bird case study. Ecosphere. In press.

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

Gehring, T.M., C.R., Blass, B.A. Murry, and D.G. Uzarski. 2020. Great Lakes coastal wetlands as suitable habitat for invasive mute swans. Journal of Great Lakes Research 46:323-329.

Gentine, J., W. Conard, K. O'Reilly, M. Cooper, G. Fiorino, A. Harrison, M. Hein, A. Moerke, C. Ruetz, D. Uzarski, and G. Lamberti. 2022. Environmental predictors of phytoplankton chlorophyll-a in Great Lakes coastal wetlands. Journal of Great Lakes Research 48(4):927-934. https://doi.org/10.1016/j.jglr.2022.04.015

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

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

Grand, J., S.P. Saunders, N.L. Michel, L. Elliott, S. Beilke, A. Bracey, T.M. Gehring, E.R. Gnass Giese, R.W. Howe, B. Kasberg, N. Miller, G.J. Niemi , C.J. Norment, D.C. Tozer, J. Wu, and C. Wilsey. 2020. Prioritizing coastal wetlands for marsh bird conservation in the U. S. Great Lakes. Biological Conservation 249: 108708. https://doi.org/10.1016/j.biocon.2020

Harrison, A.M., A.J. Reisinger, M.J. Cooper, V.J. Brady, J.J. Ciborowski, K.E. O'Reilly, C.R. Ruetz, D.A. Wilcox, and D.G. Uzarski. 2020. A Basin-Wide Survey of Coastal Wetlands of the Laurentian Great Lakes: Development and Comparison of Water Quality Indices. Wetlands, 40:465-477. https://doi.org/10.1007/s13157-019-01198

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

Heminway, A.W. and D.A. Wilcox. 2022. Response of *Typha* to phosphorus, hydrology, and land use in Lake Ontario coastal wetlands and a companion greenhouse study. Wetlands Ecology and Management 30:1167-1180.

Hilts, D.J., M.W. Belitz, T.M. Gehring, K.L. Pangle, and D.G. Uzarski. 2019. Climate change and nutria range expansion in the Eastern United States. Journal of Wildlife Management 83:591-598.

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

Hohman, T.R., R.W. Howe, D.C. Tozer, E.E.Gnass Giese, A.T. Wolf, G.J. Niemi, T.M. Gehring, G.P. Grabas, and C.J. Norment. 2021. Influence of lake levels on water extent, interspersion, and marsh birds in Great Lakes coastal wetlands. Journal of Great Lakes Research 47(2):534-545. https://doi.org/10.1016/j.jglr.2021.01.006

Horton, D.J., K.R. Theis, D.G. Uzarski, D.R. Learman 2018. Microbial community structure and microbial networks correspond to nutrient gradients within coastal wetlands of the Great Lakes. bioRxiv, 217919

Howe, R.W., E.E. Gnass Giese, and A.T. Wolf. 2018. Quantitative restoration targets for fish and wildlife habitats and populations in the Lower Green Bay and Fox River AOC. Journal of Great Lakes Research (Green Bay Special Issue): 44(5):883-894. https://doi.org/10.1016/j.jglr.2018.05.002

Howe, R.W., G.J. Niemi, L. Elliott, A.M. Bracey, W. Gaul, T.M. Gehring, E.E. Gnass Giese, G.P. Grabas, C.J. Norment, H. Panci, D. Tozer, and N.G. Walton. 2020. Birds as Indicators of Great Lakes Wetland Quality. In preparation for submission to Ecological Indicators.

Kneisel, A.N., M.J. Cooper, A.K. Monfils, S. Haidar, and D.G. Uzarski. 2020. Ecological data as a resource for invasive species management in U.S. Great Lakes coastal wetlands. Journal of Great Lakes Research. 46 (4): 910-919.

Kovalenko, K.E., L.B. Johnson, V.J. Brady, J.H.H. Ciborowski, M.J. Cooper, J.P. Gathman, G.A. Lamberti, A.H. Moerke, C.R. Ruetz III, and D.G. Uzarski. 2019. Hotspots and bright spots in functional and taxonomic fish diversity. Freshwater Science. 38:480-490. doi.org/10.1086/704713

Langer, T. A., B. A. Murry, K.L. Pangle, and D. G. Uzarski. 2016. Species turnover drives b-diversity patterns across multiple spatial and temporal scales in Great Lakes Coastal Wetland Communities. Hydrobiologia, DOI 10.1007/s10750-016-2762-2.

Langer, T.A., M.J. Cooper. L.S. Reisinger, A.J. Reisinger, and D. G. Uzarski. 2017. Water depth and lake-wide water level fluctuation influence on α- and β-diversity of coastal wetland fish communities. Journal of Great Lakes Research, In Press. 44(1): 71-76.

Lemein, T., D.A. Albert, and E.D. Tuttle. 2017. Coastal wetland vegetation community classification and distribution across environmental gradients through the Laurentian Great Lakes. Journal of Great Lakes Research 43 (4): 658-669.

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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
33. http://www.woodradio.com/articles/wood-news-125494/invasive-and-deadly-snail-found-in-13073963
34. http://www.full-timewhistle.com/science-27/great-lake-invasive-snails-kill-birds-265.html
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37. http://www.seattlepi.com/news/science/article/Snail-harmful-to-ducks-spreading-in-Great-Lakes-5959538.php
38. http://www.pendletontimespost.com/view/story/4cde108b10b84af7b9d0cfcba603cf7a/MI--Invasive-Snails/
39. http://www.wilx.com/home/headlines/Invasive-Snail-Spreading-in-Great-Lakes-285933261.html
40. http://www.watertowndailytimes.com/article/20150119/NEWS03/150118434
41. http://howardmeyerson.com/2015/01/15/scientists-invasive-snail-more-prevalent-than-thought-poses-grave-danger-to-waterfowl/

MOCK-UP OF PRESS RELEASE PRODUCED BY COLLABORATING UNIVERSITIES.

FOR IMMEDIATE RELEASE: December 9, 2014

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

USEPA-sponsored project greatly expands known locations of invasive snail

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

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

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

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

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

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

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

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

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

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