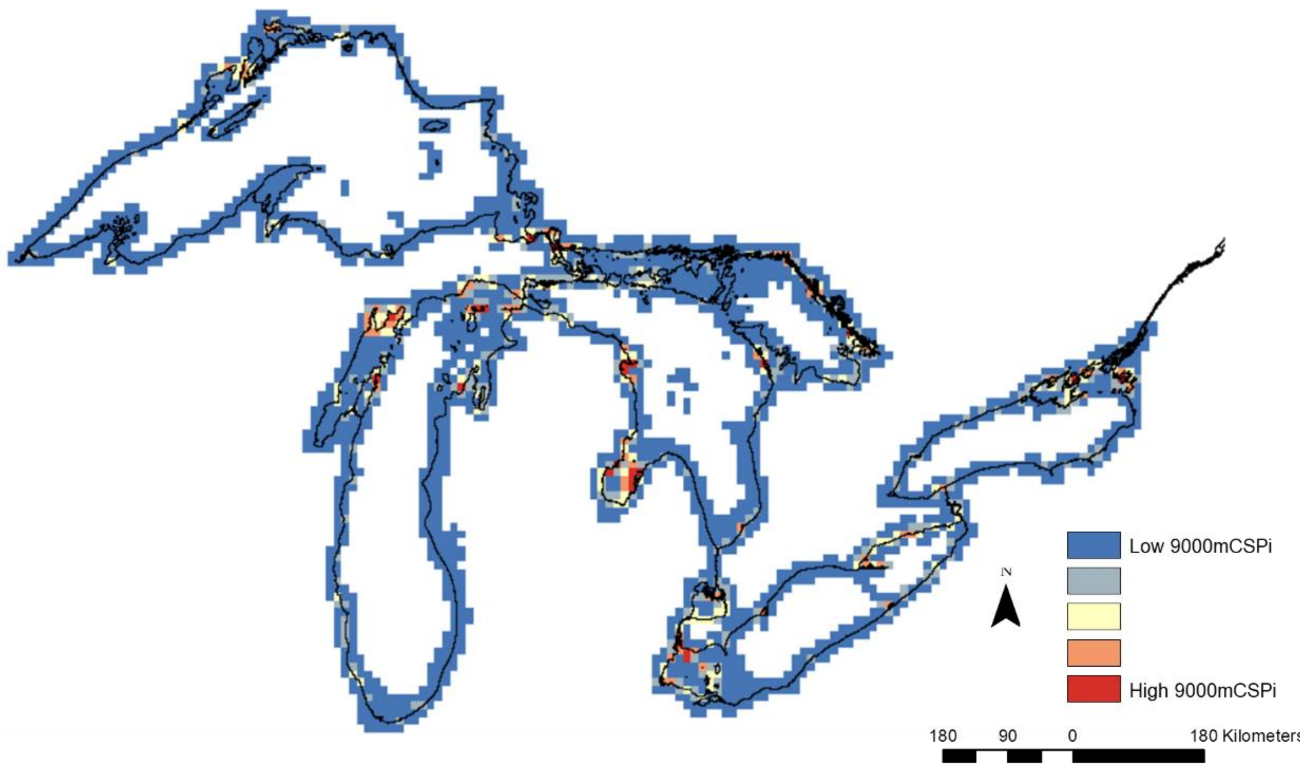
IMC Coastal Site Prioritization Process

Report of the Coastal Site Priorities Work Group

October, 2022



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Introduction

As a part of the Invasive Mussel Collaborative (IMC) September, 2019 meeting, an ad hoc group of 12 IMC members met to initially start the process of developing coastal site priorities for potential dreissenid mussel experimental control. Initial tasks included 1) a review information on where dreissenids are impacting Great Lakes resources, 2) identification of criteria for evaluating sites based on this information and other considerations, and 3) development of a process for prioritizing sites for potential management activities. During the working session, participants discussed a number of initiatives that might be useful for consideration during the prioritization process, including the GLFC lake committee environmental priorities, coastal assessments, and inventories, and developed a list of potential criteria for consideration in the prioritization process. A number of criteria were proposed for consideration including important fish spawning and nursery habitats, commercial pathways, water temperature effects on control efficacy, accessibility for control actions, long-term monitoring/assessment, terrestrial species impacts, native unionid refugia, historical/cultural sites, water quality, parks and protected areas, harmful algal blooms, and areas where phosphorus is impacting ecological function. The IMC meeting participants also discussed other issues that were identified in the IMC Strategy including ecological impacts of control, level of control needed (site-specific vs regional control). Subsequently, the participants evaluated the list of potential criteria identified and categorized them as either primary screening criteria for identifying priority sites or secondary considerations, and identified potential data sources or needs to support the criteria development (see Table 1 for the final list). The ad hoc group agreed to put together the suggested criteria into an evaluation matrix for review and refinement for the development of a coastal site prioritization process.

Table 1. Final list of primary and secondary screening criteria identified by the IMC Coastal Site Priority work group

Primary Screening Criteria	Data Needs/Sources
Native fish spawning and nursery habitat	Great Lakes Fishery Commission data
Native mussel habitat/refugia	No basinwide assessment. A possible approach is to use the Bossenbroek predictive model
Threatened and Endangered fish species location/habitat	Possible approaches include utilizing the NatureServe database, or compiling information from individual state/provincial natural heritage programs
Water intake infrastructure	Great Lakes Commission, US Environmental Protection Agency, state and provincial data
Cladophora impacts to (a) recreational use and (b) waterfowl (i.e., botulism)	Michigan Tech Research Institute (ftp://ftp.mtri.org/pub/SAV_Cladophora/)

Subsequent to the September, 2019 meeting, the Great Lakes Commission (GLC) sent a request in January 2020 to the full IMC for volunteers to serve on a formal work group to develop a coastal site prioritization process for experimental dreissenid control. Nine IMC members from state, provincial, federal, tribal, and NGO organizations volunteered to serve on the work group. A charge was subsequently drafted for the Coastal Site Priorities Work Group and was discussed and modified by the formal members of the work group during a June 11, 2020 meeting. The charge was formally adopted by the work group during a July 30, 2020 meeting. The final charge to the work group states "*This work group will review information on where dreissenids are impacting Great Lakes resources, identify criteria for evaluating sites based on this information and other considerations, and develop and implement a system for prioritizing sites for potential management activities. The outcomes will be used to inform future applied research and management activities.*" (Appendix 1). This charge links directly to the IMC Strategy Management Goal II, Objective 1 to "*Identify, evaluate, and prioritize candidate sites for zebra and quagga mussel (ZQM) control and restoration*". Over the course of 1.5 years and 9 meetings, the work group identified criteria for prioritizing sites, compiled supporting data for each of the criteria, and developed a prioritization framework. The prioritization framework resulted in development of a compiled geospatial database that was used to develop two products including 1) a static map of high/moderate priority locations for implementing experimental dreissenid control based upon spatial overlap of the criteria identified for screening purposes, by lake and 2) a decision support tool that could be modified by the user to generate different criteria weights, explore individual criteria, and explore finer-scale resolution of the criteria for specific project site selection. The prioritization process developed by the work group is intended as a potential guide for future work, but is not intended to constrain work that has or will occur in the future at other locations based upon different criteria or these criteria applied differently.

Spatial Platform, Frame, and Resolution

Given that the initial vision of the prioritization process would include mapping and a visual representation of the distribution of priority sites for experimental dreissenid control, a geospatial framework for representing the priority sites was determined as the most appropriate way to present the information. Therefore, the work group initially discussed the spatial platform, frame, and resolution that would be most suitable for the prioritization. Given that the Great Lakes Aquatic Habitat Framework (GLAHF), a spatial classification framework includes catchments, coastal terrestrial, coastal margin, nearshore, and offshore zones for the entire Great Lakes basin had already been developed (Wang et al. 2015), the work group chose to use the GLAHF platform for spatial data representation and the prioritization process. The landward and lakeward boundaries of the Great Lakes were defined based upon delineations as established by the Great Lakes Aquatic Habitat Framework Great Lakes Shoreline and Islands layer. In GLAHF, lake shorelines were defined as the ordinary high water mark elevation, or the terrestrial edge of hydrologically connected coastal wetlands (Wang et al. 2015, Gronewold et al. 2013). The coastal terrestrial zone begins at the lake shoreline and extends landward for 5 km (Wang et al. 2015). The coastal margin zone is defined as lake areas with water depth between 0-3 m for all lakes, and the nearshore zone was defined as water depths between 3-15 m for Lake Erie and 3-30 m for the other four lakes (Wang et al. 2015). The coastal terrestrial, coastal margin, and nearshore zones as defined in GLAHF are not variable through time, or with water levels but are fixed. GLAHF (www.glahf.org) is a publicly accessible Great Lakes geospatial database that consists of a series of nested grids, with resolution ranging from 30m (coastal terrestrial, coastal margin, and nearshore) and 1800m grids (offshore), all nested within a 9000m grid for the entire basin (Figure 1) as well as a number of data layers. Because the data and prioritization process were intended to include the entire Great Lakes basin, the work group increased the scale of resolution by lumping the 30m grids to 90m grids to reduce the size of the spatial data for ease of attributing and handling. GLAHF was originally developed to help with the development of priority locations for funding and specific management actions basinwide which lent itself to the IMC Coastal Site Prioritization process.

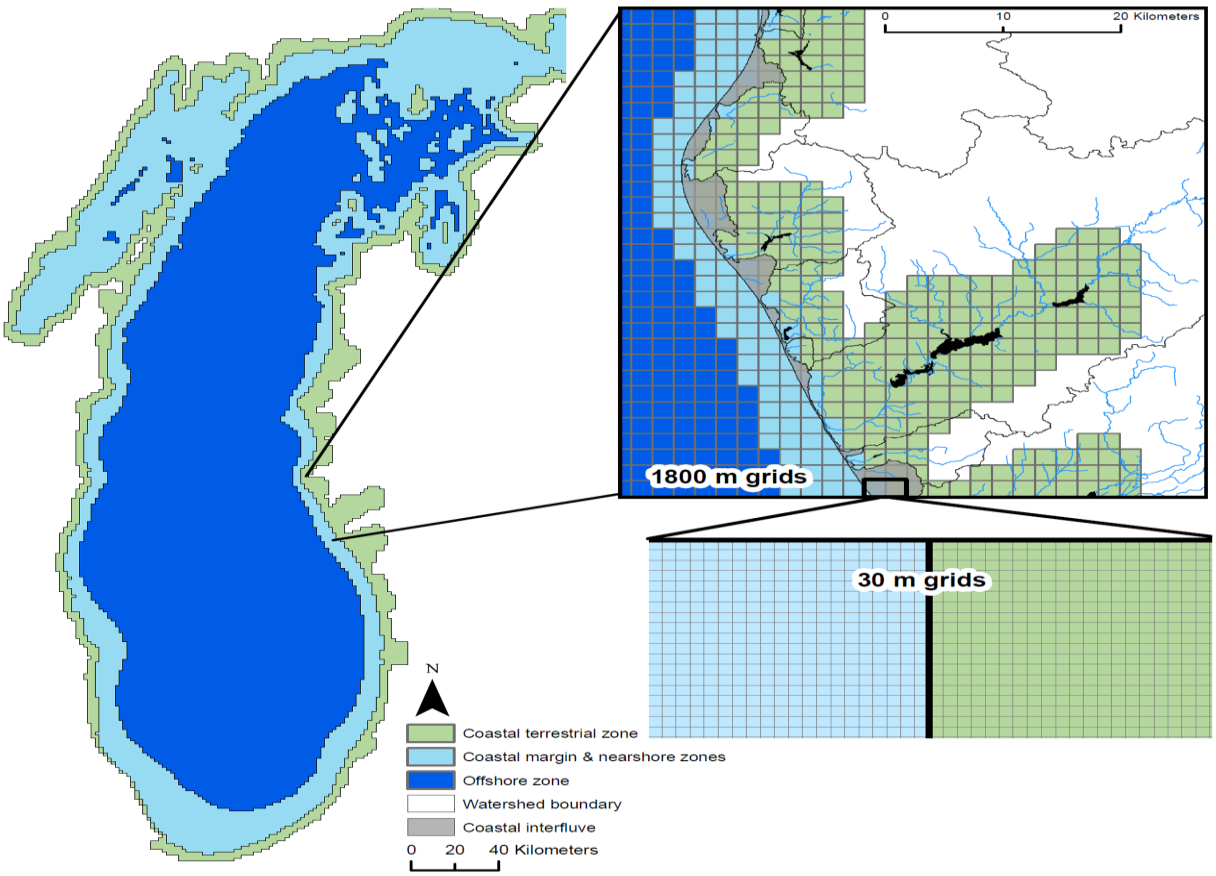

Figure 1. Example of the GLAHF spatial framework with nested spatial units ranging from 30m to 9000m.

Once the spatial data representation was chosen, the Coastal Site Priority Work Group discussed the spatial frame of the information. Given that the focus of the charge was on coastal areas, the work group constrained the data collection, processing and prioritization to the coastal terrestrial, coastal margin, and nearshore zones as delineated in the GLAHF (Figure 2).

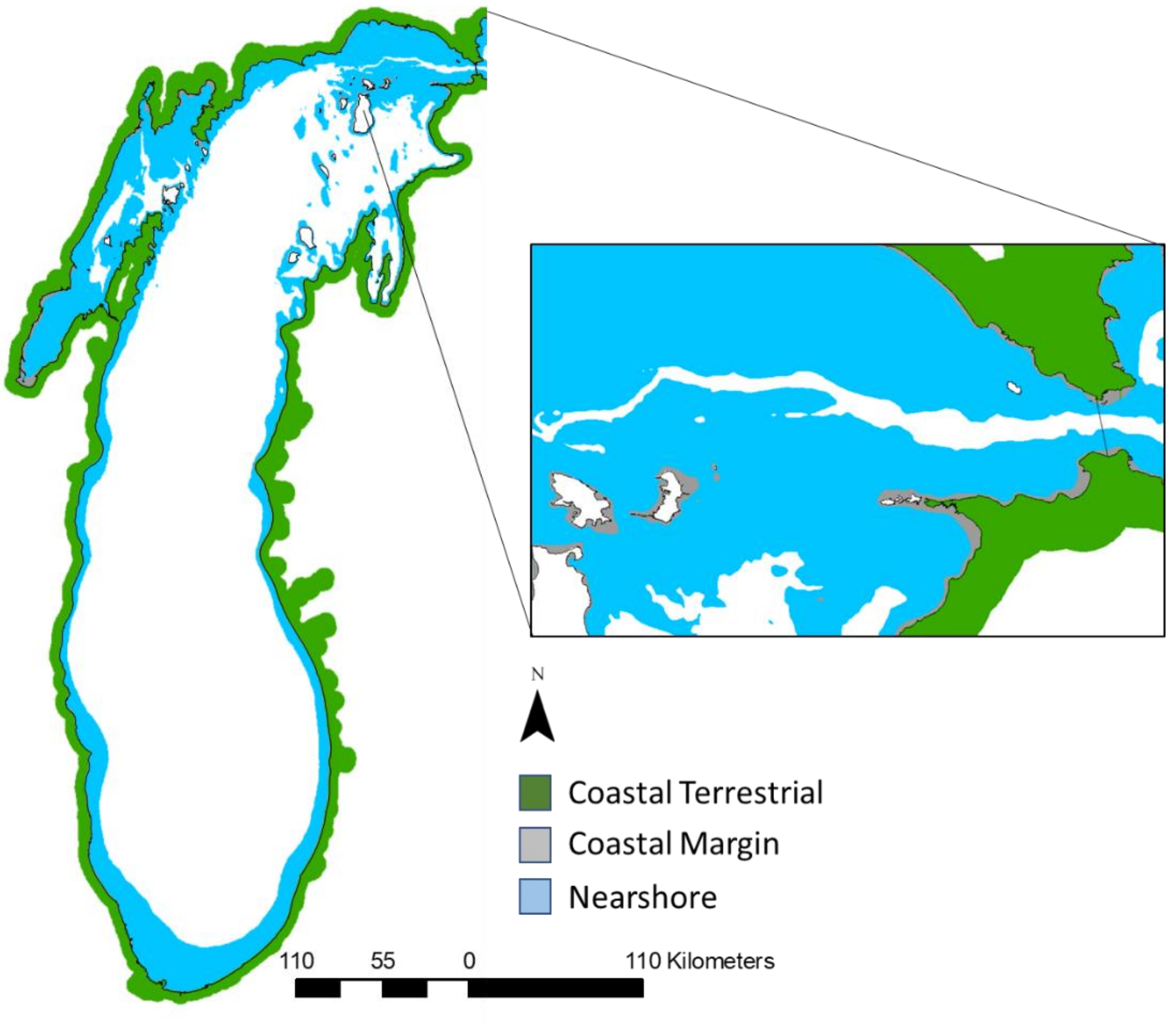

Figure 2. Spatial frame for data collection, processing, and prioritization for Lake Michigan. The frame includes the coastal terrestrial, coastal margin, and nearshore zones as established in GLAHF. The same spatial frame was used for the other Great Lakes.

Primary Criteria

After discussions, the work group recommended moving two of the criteria identified in Table 1 to secondary criteria (cultural/historical sites and availability of long-term monitoring data) and recommended adding threatened and endangered fish species to the primary criteria list. A sub-group of the work group pursued acquisition and development of the data layers for use in the prioritization process using the five primary criteria identified in the charge to the work group including 1) important fish spawning and nursery habitat, 2) native mussel habitat/refugia, 3) water intake infrastructure, 4) threatened and endangered fish species listings, and 5) cladophora distribution. These five criteria were selected because the work group determined that the data were available, or could be generated at the basinwide scale, were bi-national in nature, and could be reasonably presented in a geospatial nature. The secondary criteria identified by the work group were included as reference for individual researchers/managers for consideration once primary screening was completed, but compilation of this information was outside the scope and timeframe that was established for the work group. Descriptions of the data utilized for developing spatial layers for each of the criteria is detailed below.

Important Fish Spawning and Nursery Habitat

The native fish spawning and nursery habitat are a basinwide compilation of nearshore and coastal cisco and lake whitefish spawning shoals and larval nursery habitat as described in Coberly and Horrall (1980), Goodyear et al. (1982), Roseman et al. (2005), Zhao et al. (2009) and Ebener et al. (*in press*) (Figure 3). Spawning shoals were specifically identified and nursery habitats were delineated as adjacent shallow, soft-bottom nearshore areas (<7m depths) within the vicinity of the specific spawning shoals and were digitized in ArcGIS. Additional important nearshore and coastal spawning and nursery areas were identified for lake trout and walleye based upon similar criteria (known spawning location and adjacent nursery areas) (J. Tyson, GLFC, personal communication) and additional locations were added based upon consultations with work group members. The Native Fish Spawning and Nursery Habitat layer encompasses a combination of both spawning and nursery habitat for each delineated stock of each fish species. The delineations of important spawning and nursery areas in the Great Lakes is not an exhaustive list of spawning/nursery locations across the basin, currently or historically, but is a representation of the current known important spawning/nursery locations in the basin. No offshore spawning/nursery locations were included in the layer because this data was outside the data frame established by the work group. The native fish spawning and nursery habitat layer was clipped to the 90m coastal extent defined by the work group previously. Any 90m grid that intersected the fish spawning and nursery habitat layer was assigned an index value (S_i) of '1' indicating presence, and any 90m grid that did not intersect the layer was assigned an index value of '0' indicating absence.

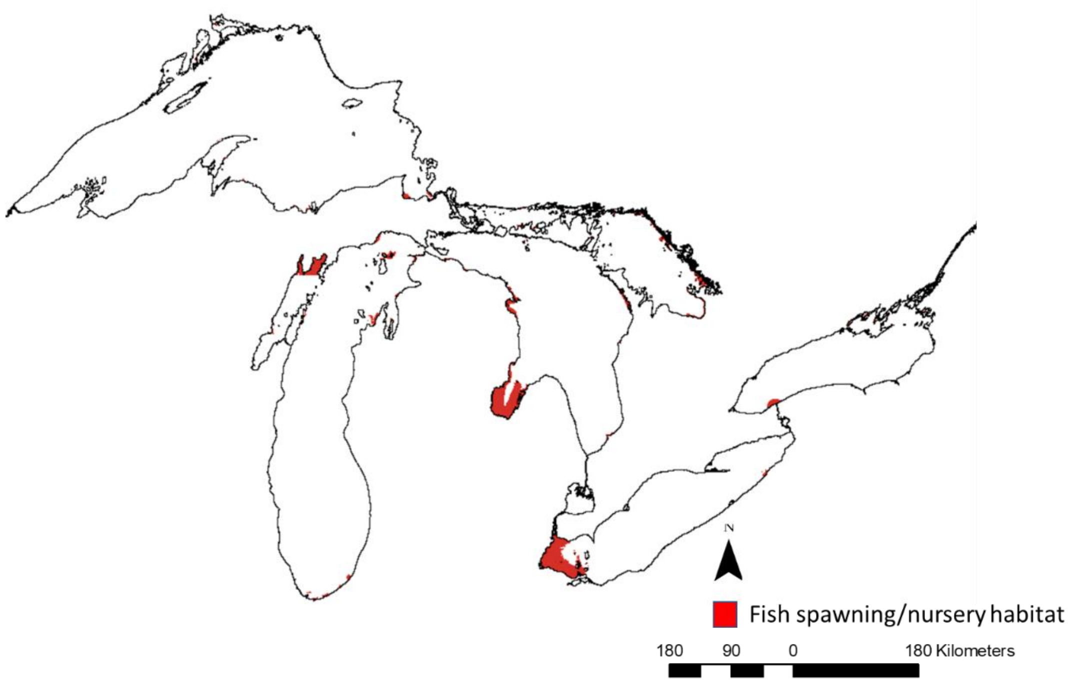

Figure 3. Basinwide important fish spawning and nursery habitat 90m resolution.

Native Mussel Refugia/Habitat

Because there are no coordinated, basinwide assessments of unionid distribution and abundance in the Great Lakes basin, the work group pursued a modeled approach to estimating unionid refugia/habitat. To predict potential unionid habitat in the Great Lakes, we developed an ecological niche model using MaxEnt (Herborg et al. 2009), with unionid data from Bossenbroek et al. (2018) and Zanatta et al. (2018), and environmental data including depth, fetch, slope, shoreline geomorphology, and sinuosity layers from GLAHF, all large-scale variables that contributed the most to the Bossenbroek et al. (2015) model for Lake Ontario. This was a presence-only model based upon the above environmental data and unionid presence information from lakes St. Clair, Erie, and Ontario (n=54 sites) which was applied to the other three Great Lakes. The output from the MaxEnt models ranged from 0 to 1, with a higher MaxEnt value indicating a better fit to the modeled ecological niche or habitat for, in this case, unionids. An importance rating for each environmental variable in the model was calculated based on a jack-knife test (Doko et al. 2011) and the model was evaluated based upon the contribution of each variable and the Area Under Curve (AUC) of the Receiver Operator Characteristics (ROC). The AUC is the probability that the model will correctly differentiate between a presence location and a random location (Phillips et al. 2006, Razgour et al. 2011). An AUC value >0.9 indicates that the model has a high ability to discriminate among locations for predicted presence or absence (Phillips et al. 2006).

Initial MaxEnt runs with all environmental variables "reasonably" predicted potential unionid distribution across the Great Lakes basin, with an AUC=0.931, however, fetch, depth, and sinuosity were the most important regional variables, with minimal contribution from shoreline geomorphology and slope. Given that shoreline geomorphology was the only categorical environmental layer, and was not important, and slope showed little importance, they were excluded from the model. Additionally, given that shoreline sinuosity and fetch are highly correlated, sinuosity was also removed from the final model. The final MaxEnt model selected by the work group contained the depth and fetch environmental layers and had an AUC=0.968, with both variables showed strong contributions (regularized training gains>0.8) to presence and unique presence. Based upon the overall AUC value and the fact that there were relatively modest regularized training gains with the addition of shoreline geomorphology, sinuousity, and slope, we felt that the depth/fetch model provided the most robust prediction of the probability of presence of unionids at the basinwide scale. Other large-scale variables that were not included in the analyses were discussed (e.g. temperature) but were deemed to be of lower importance relative to the two large-scale physical variables in the model. While local-scale variables would have likely improved the modeled distribution of unionid refugia, those data did not exist at the basinwide scale but would be useful for refinement in future site-specific analyses.

Lastly, because MaxEnt generates estimates of probability of occurrence as a continuous variable, we converted the values into a binary 'presence/absence' prediction using the minimum training presence (MTP) value (MTP = 0.3) as a conservative estimate of suitable unionid habitat across the basin (Phillips et al. 2006). Therefore, we assigned an index value (U_i) of '1' to 90m grids that intersected locations with MaxEnt probability of occurrence values > 0.3 and an index value of '0' to the others. This MTP value is the lowest predicted suitability value for an occurrence point, and essentially assumes that this is the minimum suitability value for the organism.

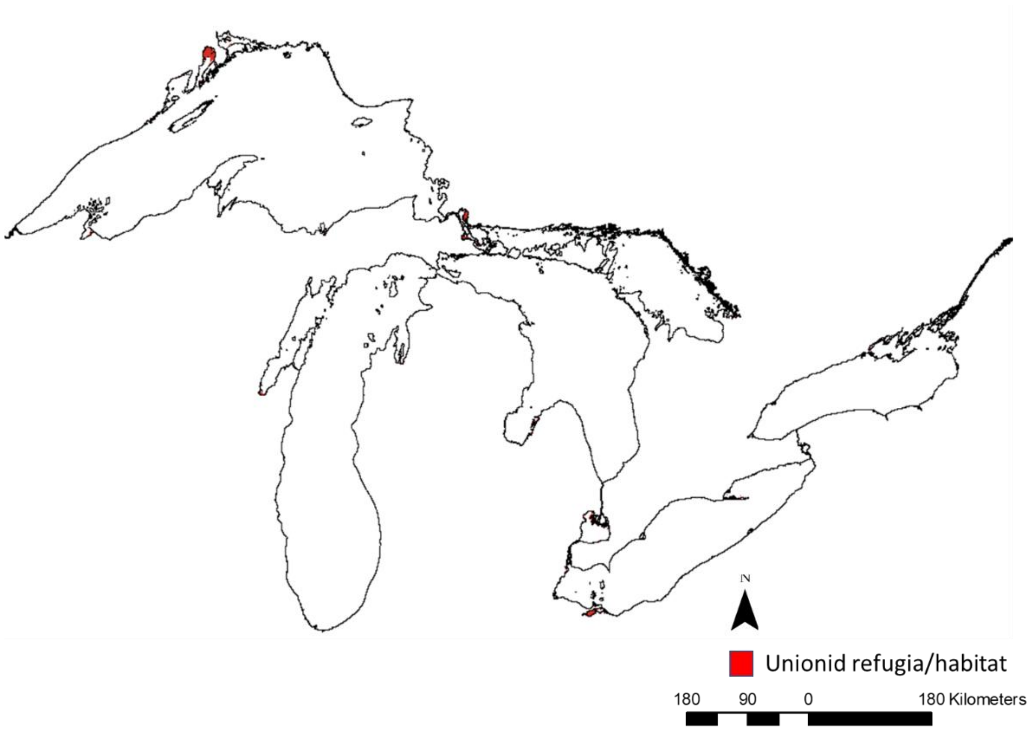

Figure 4. Unionid mussel probability of occurrence in the Great Lakes based upon MaxEnt niche model results using depth and fetch as environmental variables at the 90m resolution. Due to the scale occurrence locations are difficult to view.

Water Intake Infrastructure

To generate the data layer for water intake infrastructures, multiple data sources were procured. Sources included data from the Inland Sensitive Atlas (ISA) for jurisdictions in USEPA's Region 5 (OH, IN, IL, MI, WI, and MN), Pennsylvania Office of Water Resources Planning in the Department of Environmental Protection, the New York Bureau of Water Supply Protection, New York State Department of Health, and the Ministry of Northern Development, Mines, Natural Resources and Forestry, Water Resource Section. Because of the sensitive nature of the water intake infrastructure information, the GLC committed to restricted sharing of specific locational information for this layer, but was allowed to utilize the information in the prioritization process. The water intake infrastructure locations were clipped to the 90m coastal extent defined by the work group previously, and each intake structure was buffered out to 1km. Any 90m grid that intersected the buffered water intake infrastructure layer was assigned an index value (W_i) of '1' indicating presence, within one kilometer, of a water intake structure. Any 90m grid that did not intersect with the buffered water intake infrastructure layer was assigned an index value of '0' indicating absence. Given the restrictions on sharing this sensitive information, no figure depicting the distribution of water intake infrastructures is provided in this report but the data from this layer is utilized in the final prioritization scores at the 1800m and 9000m resolution, and an indication of the contribution of the water intake infrastructure criterion presence at the 9000m resolution is provided in the attribute table. If individuals require the raw water intake infrastructure data they are encouraged to contact each individual jurisdiction to secure permission for use (Appendix 2).

Threatened and Endangered Fish Species Listings

To generate a data layer for Threatened and Endangered fish species, the work group utilized county listing data for each state/province. This strategy was utilized because accurate catch location information for each state/province was not easily accessible, and a NatureServe data request would have been cost prohibitive. The work group felt that this approach could be used to reasonably represent the potential "risks" for consideration associated with dreissenid mussel impacts, and risks of potential experimental control on existing threatened and endangered fish species. To generate the threatened and endangered fish listings data for each county by state/province, the work group contacted staff from each of the state/provincial agencies that handle listings for threatened and endangered species and requested the currently listed species by county for all lakeshore counties. All jurisdictions provided this information or provided links that allowed access to the state listings by county. Each jurisdiction establishes threatened and endangered species listings at the county level based on documented records of occurrence in each county. Of the full list of Threatened and Endangered species listings by county, we only included fish species. Furthermore, we filtered the fish species to only include those that were associated with Great Lakes habitats based upon life history information, occurrence records, and expert opinion (Appendix 2). For example, several of the listed species only reside within tributaries, streams, or rivers and do not utilize Great Lakes proper habitat. These species were removed from the county listings. Those species that utilize a combination of streams, rivers, or tributaries and migrate to lake habitat throughout their life cycle and those species that occur within a Great Lake proper remained on the list (Table 2). Additionally, if a species historically occurred within a Great Lake but had not been recorded or anecdotally reported to be found within the Great Lakes since 1960, the species was presumed extirpated and removed from the list. Other threatened and endangered fish species that were not included in Table 2. were those that were anecdotally suggested to not be present in the Great Lakes, were not considered a genetically distinct species, or were not considered a native species to the Great Lakes.

Table 2. Final list of Threatened (T) and Endangered (E) fish species utilizing the Great Lakes used for development of the threatened and endangered fish species listing index layer.

Common Name	Scientific Name	State Listing Status	Common Name	Scientific Name	State Listing Status
Sauger	*Sander canadensis*	T	Starhead Topminnow	*Fundulus dispar*	E
River Darter	*Percina shumardi*	E	Northern Madtom	*Noturus stigmosus*	E
Channel Darter	*Percina copelandi*	E/T	Tadpole Madtom	*Noturus gyrinus*	E
Lake Sturgeon	*Acipenser fulvescens*	E/T	Blacknose Shiner	*Notropis heterolepis*	E
Lake Herring	*Coregonus artedi*	E/T	Warmouth	*Lepomis gulosus*	E
Shortjaw Cisco	*Coregonus zenithicus*	T	Bigmouth Buffalo	*Ictiobus cyprinellus*	E
River Redhorse	*Moxostoma carinatum*	T	Iowa Darter	*Etheostoma exile*	E

Common Name	Scientific Name	State Listing Status	Common Name	Scientific Name	State Listing Status
Pugnose Shiner	*Notropis anogenus*	E/T	Northern Redbelly Dace	*Chrosomus eos*	E
Longnose Sucker	*Catostomus catostomus*	E/T	Mooneye	*Hiodon spp.*	T
Spotted Gar	*Lepisosteus oculatus*	E	American Eel	*Anguilla rostrata*	E
Western Banded Killifish	*Fundulus diaphanus*	E/T	Shortnose Cisco	*Coregonus reighardi*	E
Blackchin Shiner	*Notropis heterodon*	E/T	Lake Chubsucker	*Erimyzon sucetta*	T
Cutlip Minnow	*Exoglossum maxillingua*	T	Silver Chub	*Macrhybopsis storeriana*	T
Brindled Madtom	*Noturus miurus*	T	Eastern Sand Darter	*Ammocrypta pellucida*	E/T
Greater Redhorse	*Moxostoma valenciennesi*	E/T	Northern Sunfish	*Lepomis peltastes*	T
Pugnose Minnow	*Opsopoedus emilia*	E			

Based upon the listings of threatened and endangered fish species that would potentially be in the Great Lakes, and affected by dreissenids at some life history stage, we generated an index. The index was calculated at the county level (both state and provincial) and was based upon the screened list of species at the county level (Appendix 3). For several species, the listing status varied (endangered vs threatened) based upon the county/state/province in which it is listed but this was accounted for in the county index values. The index was calculated as the frequency of the listed species from Table 2 (both threatened and endangered) + the frequency of endangered species from Table 1 for each county. The index calculation method more heavily weighted counties with a higher frequency of endangered species, while also accounting for threatened species listings. This index value (I) was then standardized to range from 0-1 (T_i), consistent with the range of values for the other criteria. Because of differences in how states/provinces handled species listings we had to make one adjustment. Pennsylvania was very aggressive with their regulatory listings for fish species (e.g. Erie County, PA I=27) while most other state/provincial index values (I) ranged from 0-13. Due to this difference in listing policy for threatened and endangered species listings, we standardized the index values (T_i) to a range of 0-1 $(I-I_{min})/(I_{max}-I_{min})$ based upon a maximum index value of 13 (I_{max}=13), and assigned the PA counties a standardized T_i value of 1. The threatened and endangered fish index layer was then clipped to the 90m coastal extent defined by the work group previously and each 90m grid was assigned the threatened and endangered species standardized index value (T_i), which ranged from 0-1. For additional information, credits, and state contacts please see the Coastal Site Priorities metadata.

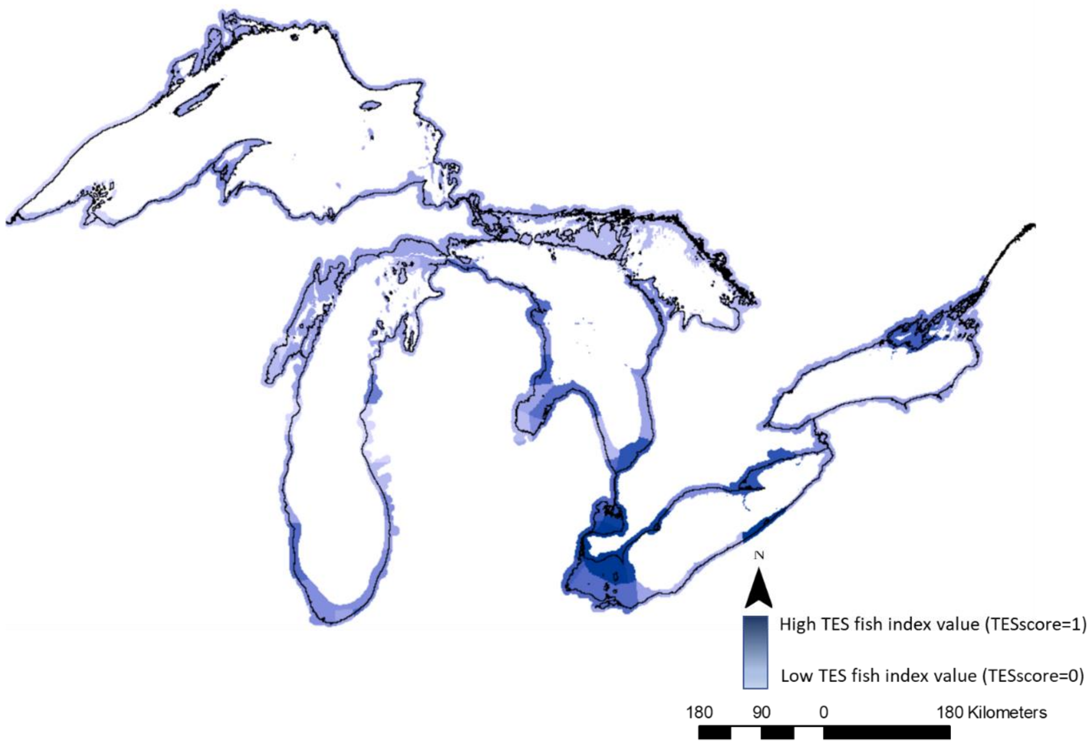

Figure 6. Threatened and endangered fish species index values in the Great Lakes based upon the above methods at the 90m resolution.

Cladophora Distribution

For this criteria data layer, we utilized information generated by the Michigan Tech Research Institute (MTRI) under Great Lakes Restoration Initiative (GLRI) funding, which represents the extent of Submerged Aquatic Vegetation (SAV) in the optically shallow areas (areas where there is a return of light from the bottom) of each of the Great Lakes (Brooks et al. 2015). The SAV identified in this data layer is predominantly Cladophora with localized areas of vascular plants, other filamentous macroalgae, and diatoms. The data, which was generated at a 30m resolution, was generated using an MTRI-developed depth-invariant algorithm and utilized LandSat data from 2017-2020 collected on cloud-free days during the vegetative growing season (March-September). Some areas within each Great Lake were not classifiable due to consistently high turbidity. SAV classes included in the MTRI basinwide map include SAV_CLASS=1 (light submerged aquatic vegetation), SAV_CLASS=3 (unclassified due to turbidity), SAV_CLASS=7 (dense submerged aquatic vegetation), and SAV_CLASS=9 (sand). Only SAV_CLASS 1 and 7 (light and dense SAV) were included in the analysis. For this data layer, any 90m grid that intersected a 30m grid that had a SAV_CLASS value of 1 was assigned an index value (C_i) of '0.5' indicating 'light SAV'. Any 90m grid that intersected a 30m grid that had a SAV_CLASS index value of 7 was assigned an index value (C_i) of '1.0' indicating 'heavy SAV'. Any 90m grid that intersected a 30m grid that had a SAV_CLASS value of 3 or 9 (sand or unclassified) was assigned an index value (C_i) of '0.0'. If multiple SAV_CLASS values fell within a 90m grid the maximum index value of the range was assigned to the grid.

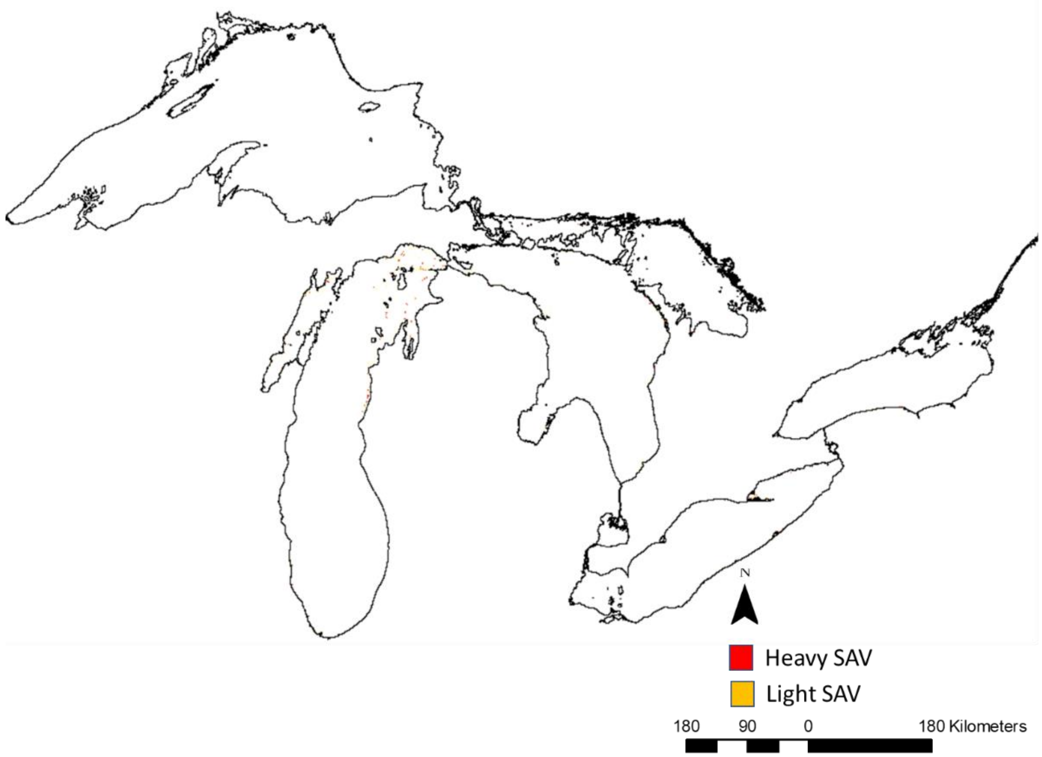

Figure 7. SAV distribution in the Great Lakes based upon MTRI derived depth-invariant algorithm utilizing Landsat satellite data from 2017-2020 collected during the vegetative growing season (March-September). Due to the scale, occurrence locations are difficult to view.

Secondary Criteria

A range of secondary criteria were identified by the work group for consideration by parties implementing experimental mussel control after primary screening (Appendix 1). The secondary criteria fell primarily into four categories including:

1. Ecological criteria
    a. Stage of mussel invasion/population status
    b. Connectivity to other important habitats
2. Infrastructure criteria
    a. Long-term assessment/monitoring data
    b. Existing/ongoing investments in the vicinity
    c. Other fish habitat restoration activities in the vicinity
3. Cultural/historical criteria
    a. Recreational boat usage
    b. Recreational/commercial/subsistence fishing effort
    c. Beach usage
    d. Importance for focal commercial/recreational fisheries
4. Implementation/operational criteria
    a. Access/proximity to marinas
    b. Depth (*is accounted for in the spatial frame of the prioritization*)
    c. Exposure (e.g. current, wave action)

Because many of the secondary criteria were either unavailable at the basinwide scale, or would have required significantly more effort than the work group had to acquire, the work group decided that development of the primary criteria as an initial screening level tool was the most efficient use of time. As individual researchers or agencies further develop implementation, they may choose to explore the secondary criteria on a case-by-case basis, given the limited data availability for these criteria.

Prioritization Process

While developing the primary criteria layers, the work group had a number of discussions about ways to develop a prioritization process. The work group agreed that development of a screening stage prioritization process, at the 9000m resolution which aggregated information from the 90m resolution up to the 9000m would be the most valuable and manageable process for prioritization. The work group agreed that developing the prioritization process based upon the spatial extent of overlap of all of the primary criteria (modified presence/absence) would meet the intent of the charge. Therefore, the prioritization process should identify spatially where multiple criteria overlap, aggregated at the 9000m resolution, and further prioritize areas with significant overlap in the criteria as moderate and high priority locations. The work group also agreed that each individual criterion, using this methodology, should be equally, positively weighted and this would indicate locations across the basin where dreissenids were having the most significant impact on a broad range of resources identified in the IMC Strategy, in combination. The work group recommended that the impact of each criterion on the overall prioritization score also be detailed for each priority 9000m grid, so that individuals could evaluate which criteria were most important for the prioritization score and allow for further refinement based upon experimental control application/operational constraints (e.g. non-specific molluscicide application). Additionally, the work group recommended that products from the work group should include 1) static maps of high and moderate priority locations at the 9000m scale, by lake, for guiding potential management actions and 2) a decision support tool with the individual primary criteria at the 90m resolution, which will allow others to further refine information for site-specific implementation, and/or allow for individuals to utilize the information for single criteria or customized prioritization based upon specific funding opportunities (to address only cladophora, for example).

To address the work group recommendations, the sub group assembled the primary criteria layers at the 90m grid resolution and constructed a Coastal Site Priorities Index (90mCSPi) value. The $90mCSP_i$ value for each grid was the sum of the scores for the 1) important fish spawning and nursery habitat index (S_i), 2) cladophora index (C_i), 3) Unionid refugia index (U_i), 4) Water Intake infrastructure index (W_i), and 5) threatened and endangered species listing index (T_i) (e.g. $90mCSP_i=(\sum S_i, C_i, U_i, W_i, T_i)$. Because each criterion's index value was standardized to range from 0-1 (equally weighted), the $90mCSP_i$ values theoretically could range from 0-5 with a $90mCSP_i=5$ indicating that all 5 criteria were present in that location at the maximum value for each criterion. The realized range of $90mCSP_i$ values was 0-4.2.

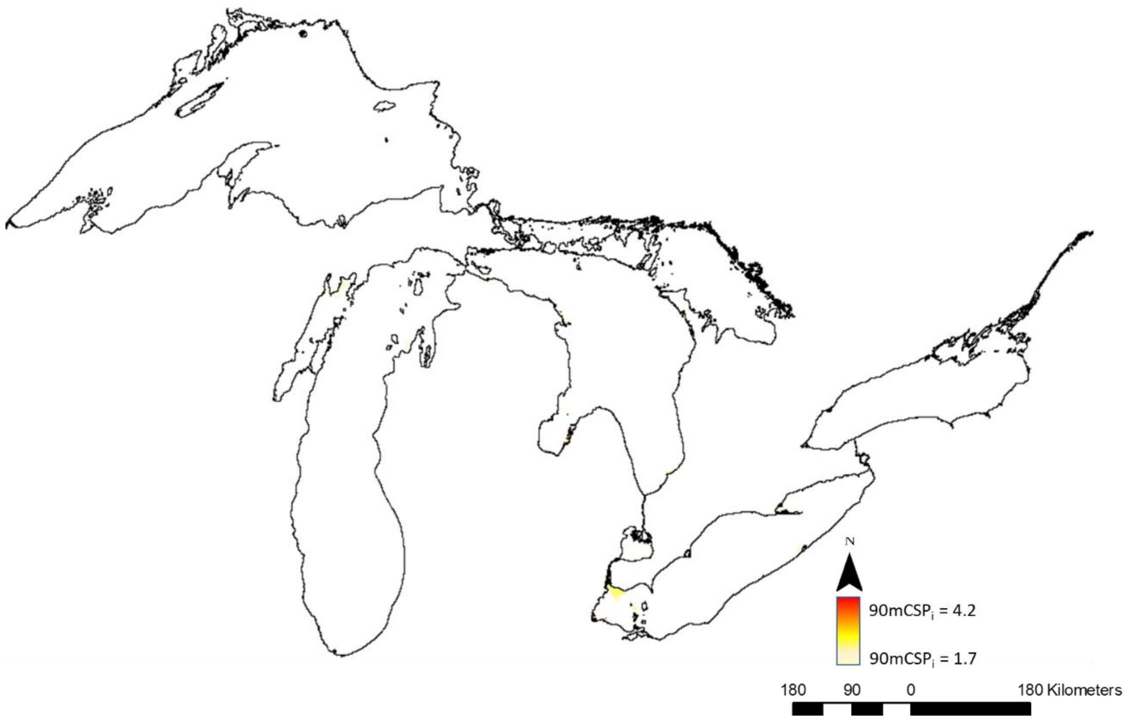

Figure 8. 90mCSP$_i$ values across the Great Lakes basin. Due to the scale, occurrence locations are difficult to view.

Because of the challenges associated with working at the basinwide scale at the 90m resolution (14.1 million records) for our data frame, we next aggregated the data to the 1800m resolution for generating the priority sites for ease of processing and viewing. To do this, we assigned the **maximum** 90mCSP$_i$ value to the 1800m grid that it was nested in. To establish a threshold for the prioritization we utilized Jenks natural breaks optimization, a data clustering method that minimizes each class's average deviation from the class mean, while maximizing each class's deviation from the means of other classes, with five classes. We chose to retain grids that had 1800mCSP$_i$ values that fell in the top two classes (1800mCSPi$\geq$1.7) as the minimum threshold for considering overlap of the primary criteria (Figure 9). Grids that had a 1800mCSP$_i$ $\geq$ 1.7 had at least two criteria that overlapped in the area at the 90m resolution, and in many cases more than two overlapping criteria. Therefore, we only retained those grids with 1800mCSP$_i$ values $\geq$ 1.7 for further prioritization, which allowed for retaining generalized locations where a number of the primary criteria overlapped. One caveat that users need to be aware of is that there are some inherent issues introduced with the 1800mCSP$_i$ values for each grid, given that the grids are square and the shoreline is sinuous. For grids that occur in the coastal terrestrial zone completely or partially, the 90mCSP$_i$ values may be influenced by primary criteria that have "no data". For example, "Important Fish Spawning and Nursery Habitat", "Cladophora", "Unionid Refugia" and "Water Intake Infrastructure" layers were clipped to the shoreline, so any 1800mCSPi grids that intersect with the shoreline layer will have "no data" cells influencing the 1800mCSP$_i$ score. Inland lake or tributary data were not included in the data layers developed for the Great Lakes.

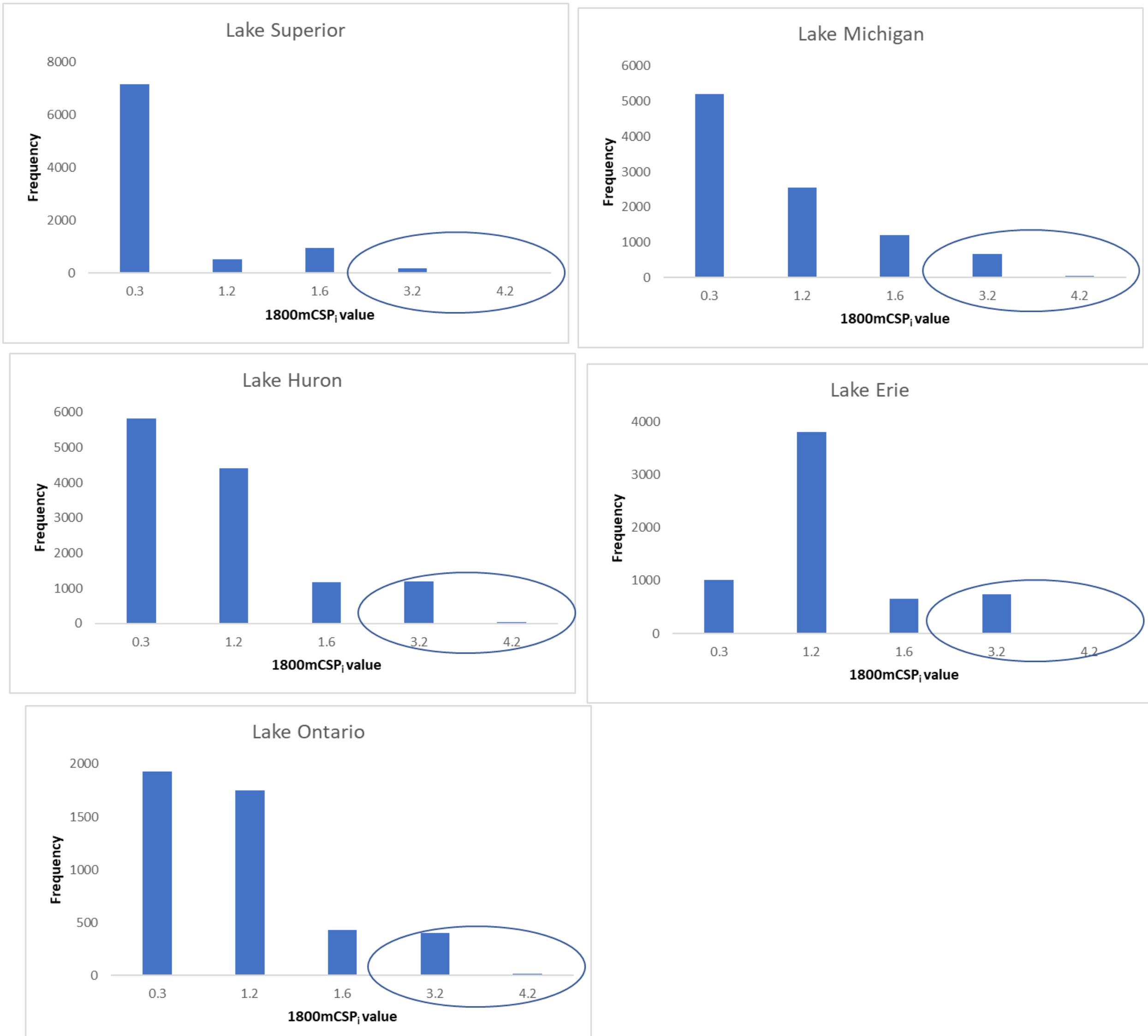

Figure 9. Frequency histogram of 1800mCSP$_i$ scores by lake. Bin sizes were established by specifying five classes and using Jenks natural breaks optimization. 1800mCSP$_i$ scores $\geq$ 1.7 were used to scale up from 1800m to 9000m resolution for prioritization process are highlighted in the figure.

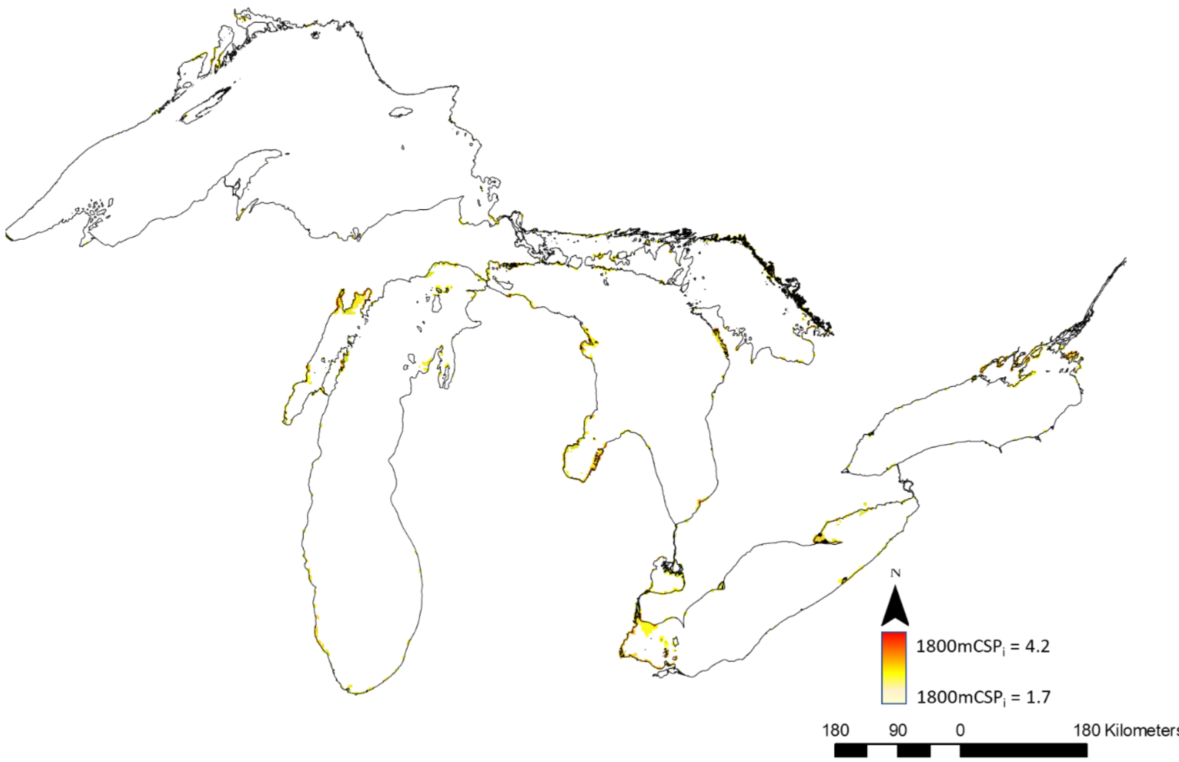

Figure 10. 1800mCSP$_i$ values across the Great Lakes basin. Due to the scale, occurrence locations are difficult to view.

Lastly, because the charge to the Coastal Site Priorities Work Group was to prioritize candidate "sites" for implementing experimental mussel control, but there is likely interannual variability in distribution of some of the primary criterion, and the fact that the 1800mCSP$_i$ values were well dispersed across the basin, the sub-group chose to further aggregate the 1800mCSP$_i$ values to the 9000m grid resolution. This aggregation was based upon the ***frequency*** of 1800mCSP$_i$ values $\geq$ 1.7 nested within each 9000m grid (9000mCSP$_i$) (Figures 11-13) and should best represent the distribution of moderate and high priority sites at a scale that allowed for refinement based upon evaluation of finer-scale resolution data, further reconnaissance, updated data, or secondary criteria, and will allow for likely interannual variability in distribution of some of the criterion. The theoretical maximum frequency of 1800mCSP$_i$ values in each 9000m grid $\geq$ 1.7 was 25 (25 1800m grids nested in the 9000m grid) and the realized maximum frequency value was 25. This frequency value represents a quasi-index of the area within the 9000m grids where multiple criteria overlap. Figure 11 demonstrates the prioritization process and spatial aggregation of index values from the 90m to 9000m resolution scale. One caveat that users need to be aware of is that there are some inherent issues introduced with the 9000mCSP$_i$ values for each grid, given that the grids are square and the shoreline is sinuous. For grids that occur in the coastal terrestrial zone completely or partially, the 90mCSP$_i$ values may be influenced by primary criteria that have "no data". For example, "Important Fish Spawning and Nursery Habitat", "Cladophora", "Unionid Refugia" and "Water Intake Infrastructure" layers were clipped to the shoreline, so any 9000mCSPi grids that intersect with the shoreline layer will have "no data" cells influencing the 9000mCSP$_i$ score. Inland lake or tributary data were not included in the data layers developed for the Great Lakes.

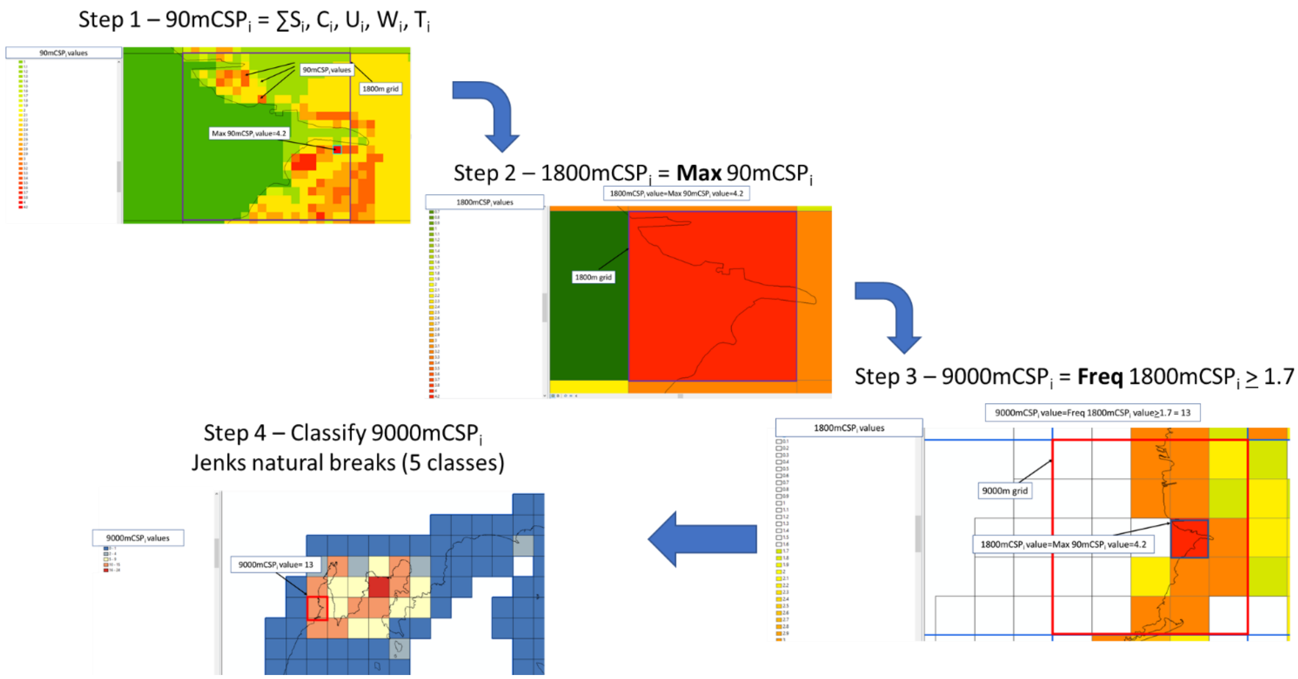

Figure 11. Prioritization process and aggregation from 90m to 9000m for identifying coastal site priorities. This example is for the Bays de Noc region of Lake Michigan.

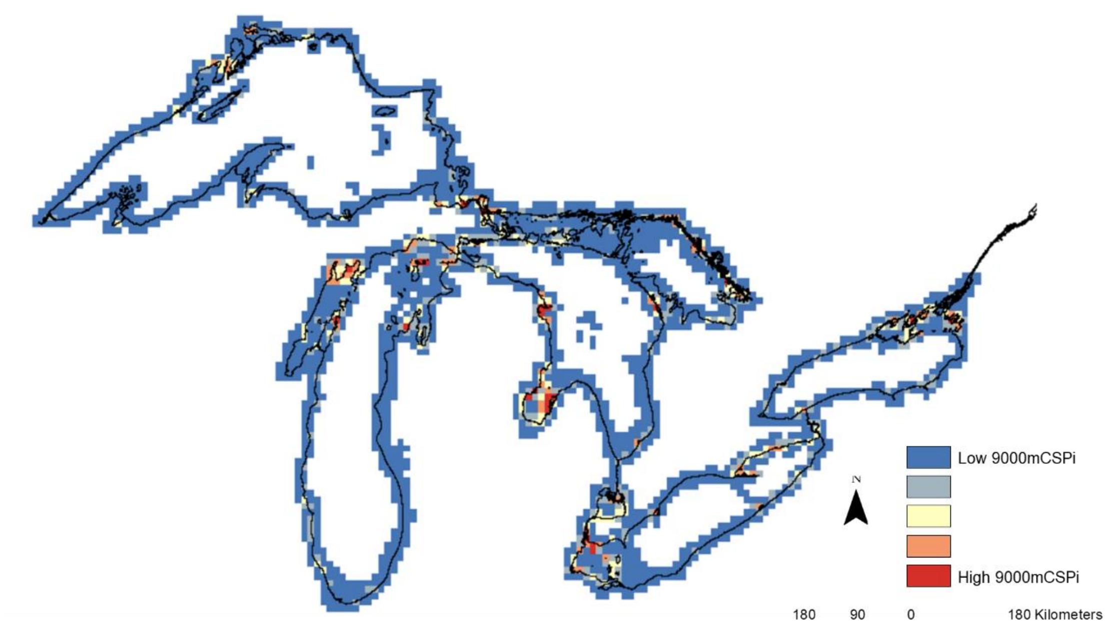

Figure 12. Basinwide $9000mCSP_i$ values based upon frequency of 1800mCSP values $\geq$ 1.7 in each 9000m grid. Classifications are based upon Jenks natural breaks optimization with 5 classes, which are unique to each lake.

To classify high and medium priority 9000m “sites”, the work group utilized the Jenks natural breaks optimization function in ArcGIS with five classes, and selected the top two classes as moderate and high priority sites for each lake (Figures 12 and 13). While the determination to utilize five classes and select the top two classes for the prioritization was subjective, this strategy resulted in a reasonable number of high (n=1-13) and moderate (n=6-23) sites, for each lake (Figures 12 and 13).

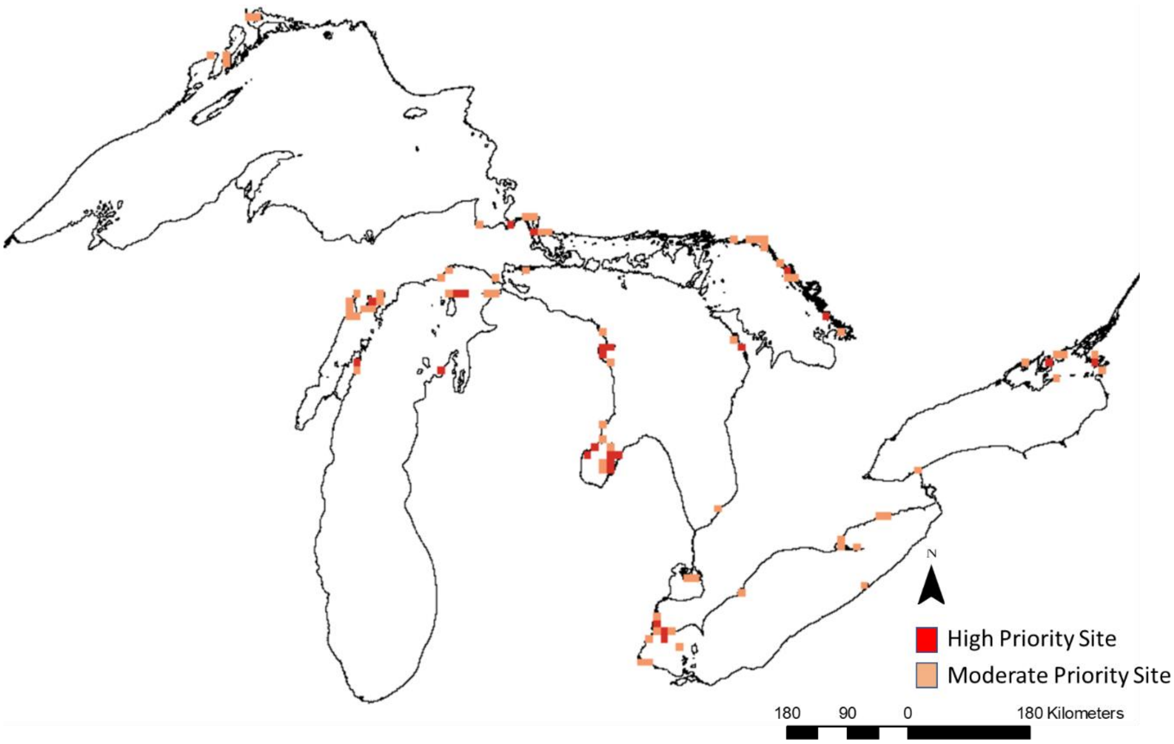

Figure 13. Basinwide 9000mCSP$_i$ high and moderate priority sites based upon frequency of 1800mCSP values$\geq$ 1.7 in each 9000m grid. High priority and moderate priority sites classified from Jenks natural breaks optimization with frequency values ranging from 12-24 for high priority sites, and frequency values ranging from 7-11 for moderate priority sites in each lake.

To address the recommendation from the work group to develop an “index” for each priority grid at the 9000m scale which would indicate which criteria were driving the prioritization scores, the sub group included fields in the associated attribute tables which summed the contribution for each criteria at the 90m resolution (values ranged from 0-1) to the 9000m prioritization value. The theoretical maximum contribution for each criteria at the 90m resolution to the 9000m prioritization score is 10,000. The higher the value for each criteria, the more it is contributing to the final 9000m prioritization score (Table 3).

Table 3. Example of the attribute tables with summed criteria index scores for Lake Huron, which indicates the contribution of each criteria to the overall 9000mCSP$_i$ prioritization values (see Appendix 4 for the full Lake Huron table as well as tables for the other four lakes). The maximum possible summed value for each index is 10,000, which would indicate that the maximum value for that criteria was in achieved in every 90m grid cell.

9000m Grid	9000m CSP$_i$	Sub Basin	Site	Priority	Fish Habitat Index	Unionid Index	Water Intake Index	Cladophora Index	Threatened and Endangered Fish Index
11220	25	Saginaw Bay	South Saginaw Bay	High	9904	87	0	1632	5000
14140	22	North Channel and Georgian Bay	Lookout Island	High	4778	1508	0	16.5	880
9911	19	St. Marys River	Lake Nicolet	High	0	2263	0	203	1520
9909	16	St. Marys River	Churchville	Moderate	0	3798	240	186.5	1280
15044	13	North Channel and Georgian Bay	Beausoliel Bay	Moderate	114	1205	0	256.5	520
11208	13	Central Lake Huron	Thunder Bay	Moderate	3413	11	0	392.5	2200

For example, in Table 3 above, fish spawning and nursery habitat, cladophora, and threatened and endangered species criteria all contribute heavily to the high priority ranking for grid 11220. For grid 9909, unionid refugia, water intake infrastructure, and threatened and endangered species contribute to the moderate priority ranking. Including the contribution of each criteria to the overall 9000mCSP$_i$ value should allow users to exclude, or include, locations that have a high prevalence of one criterion (e.g. potential unionid refugia or threatened and endangered fish species listings), depending upon the experimental control method or objectives.

Results

Lake Superior

For Lake Superior, a total of 7 (of 605) 9000m grids were identified as high or moderate priority sites for implementing potential management actions for ZQM control (Figure 14). One high priority site was identified in Whitefish Bay (Gros Cap) based upon the presence of important fish spawning and nursery habitat, unionid refugia, relatively high threatened and endangered fish species listing index value, and cladophora. Six moderate priority 9000m grids were identified in Tahquamenon, Black, Thunder, and Nipigon bays based upon presence of important fish spawning and nursery habitat, unionid refugia, and threatened and endangered fish species listing index values. While most of Lake Superior has not been colonized by dreissenid mussels, there is an ongoing colonization event occurring in Nipigon Bay (Fritz Fischer, personal communication) and this was a location identified as a potential site for experimental management action.

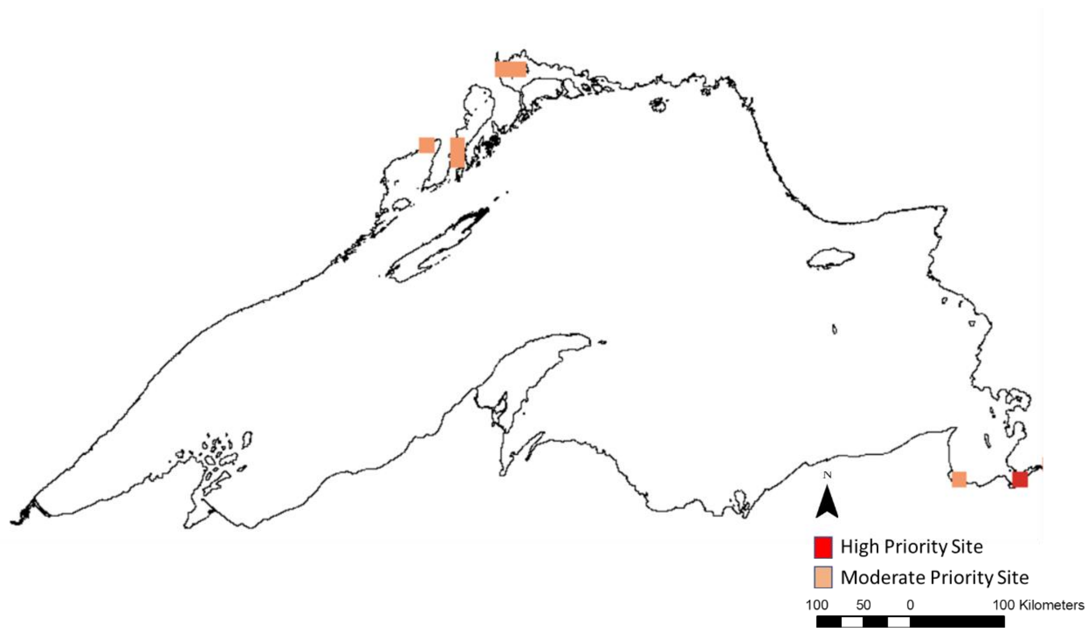

Figure 14. Lake Superior 9000mCSP_i high and moderate priority sites based upon frequency of 1800mCSP values$\geq$ 1.7 in each 9000m grid. High priority and moderate priority sites classified from Jenks natural breaks optimization with frequency values ranging from 12-17 for high priority sites (n=1), and frequency values ranging from 7-11 for moderate priority sites (n=6).

Lake Michigan

For Lake Michigan, a total of 21 (of 568) 9000m grids were identified as high or moderate priority sites for implementing potential management actions for ZQM control (Figure 15). A total of five high priority sites were identified in Big Bay de Noc, North Moonlight Bay, Good Harbor Reef, and in the Hog-Garden Island region. The high priority scores were based upon the presence of important fish spawning and nursery habitat, high cladophora density, and relatively high threatened and endangered fish species listing index values. A total of 16 moderate priority sites were identified in Lake Michigan and included the above sites as well as Sturgeon Bay, Naubinway, Little Bay de Noc, and Point aux Chenes based upon presence of important fish spawning and nursery habitat, unionid refugia, cladophora density, and threatened and endangered fish species listing values, variously (Appendix 4). All of the high and moderate priority 9000m grids were in the northern portion of Lake Michigan and an experimental action has occurred at one of the high priority locations (Good Harbor Reef).

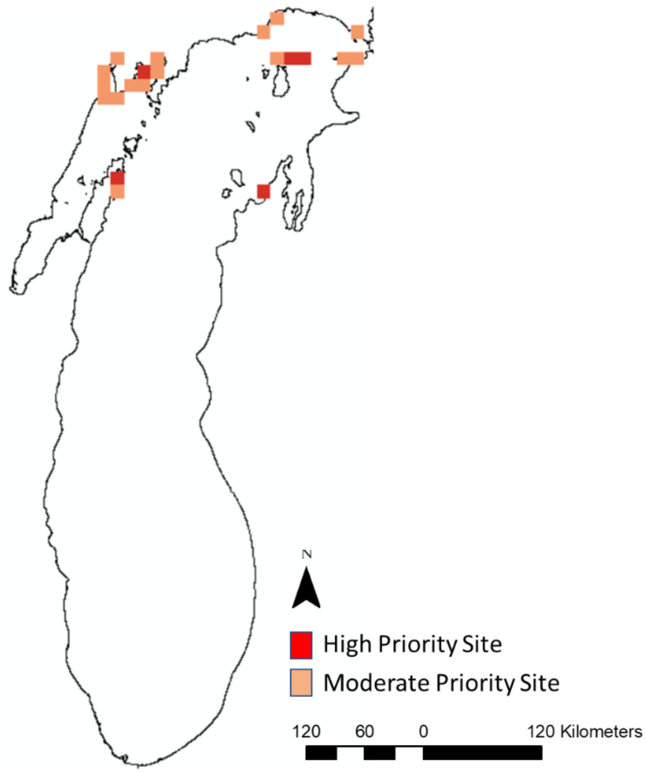

Figure 15. Lake Michigan 9000mCSP$_i$ high and moderate priority sites based upon frequency of 1800mCSP values $\geq$ 1.7 in each 9000m grid. High priority and moderate priority sites classified from Jenks natural breaks optimization with frequency values ranging from 16-24 for high priority sites (n=5), and frequency values ranging from 10-15 for moderate priority sites (n=16).

Lake Huron

For Lake Huron, a total of 36 (of 723) 9000m grids were identified as high or moderate priority sites for implementing potential management actions for ZQM control (Figure 16). A total of 13 high priority sites were identified in southern and northern Saginaw Bay, Thunder Bay, Lake Nicolet, the Fishing Islands, and the North Channel and Georgian Bay (Lookout Island and Big David Bay). The high priority scores were based upon the presence of important fish spawning and nursery habitat, high cladophora density, unionid refugia, and relatively high threatened and endangered fish species listing index values. A total of 23 moderate priority sites were identified in Lake Huron and included the above sites as well as Middle Island, East Tawas, Cedarville, Kettle Point, the St. Marys River (Churchville, Pine Island, Campment Island), and the North Channel and Georgian Bay (French River, Philip Edward Island, Georgian Inlet, Beausoliel Bay) based upon presence of important fish spawning and nursery habitat, unionid refugia, cladophora density, and threatened and endangered fish species listing index values, variously (Appendix 4). Lake Huron had the highest frequency of high and moderate priority sites due to a high frequency of locations with important fish spawning and nursery habitat, unionid refugia, and high index values for threatened and endangered fish species.

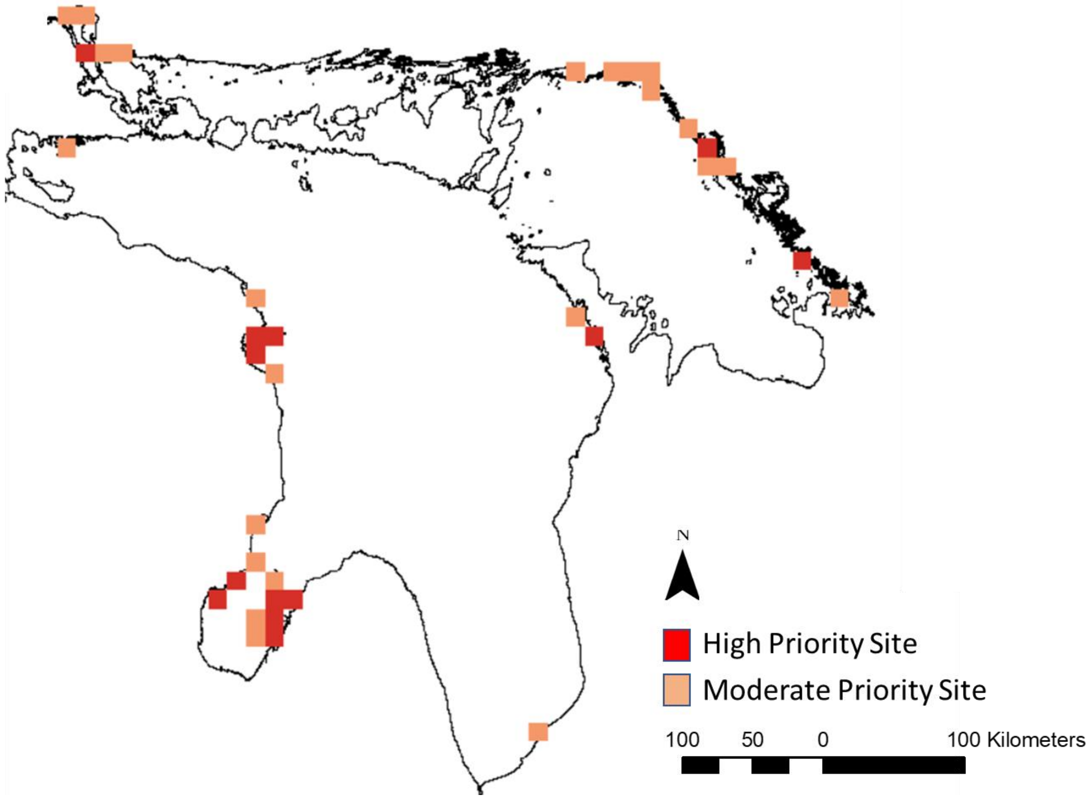

Figure 16. Lake Huron 9000mCSP$_i$ high and moderate priority sites based upon frequency of 1800mCSP values$\geq$ 1.7 in each 9000m grid. High priority and moderate priority sites classified from Jenks natural breaks optimization with frequency values ranging from 18-24 for high priority sites (n=13), and frequency values ranging from 12-17 for moderate priority sites (n=23).

Lake Erie

For Lake Erie, a total of 19 (of 364) 9000m grids were identified as high or moderate priority sites for implementing potential management actions for ZQM control (Figure 17). A total of three high priority sites were identified in western Lake Erie and the Detroit River. Western Lake Erie high priority scores were based upon the presence of important fish spawning and nursery habitat and high threatened and endangered fish species listing index values. For the Detroit River, high priority scores were primarily a function of the presence of important fish spawning and nursery habitat, unionid refugia, water intake infrastructure, and high threatened and endangered fish species listing index values. A total of 16 moderate priority sites were identified in Lake Erie and included the above sites as well as Long Point, Maumee, Rondeau, and Presque Isle bays, the Grand River mouth, ON, Lake St. Clair delta, Monroe, and Hen Island complex based upon presence of important fish spawning and nursery habitat, unionid refugia, cladophora density, water intake infrastructure and threatened and endangered fish species listing index values, variously (Appendix 4). Cladophora distribution was not predicted well for the western end of Lake Erie due to high turbidity and the SAV index may overestimate cladophora distribution in Long Point, Rondeau, and Presque Isle bays due to significant amounts of vascular plants.

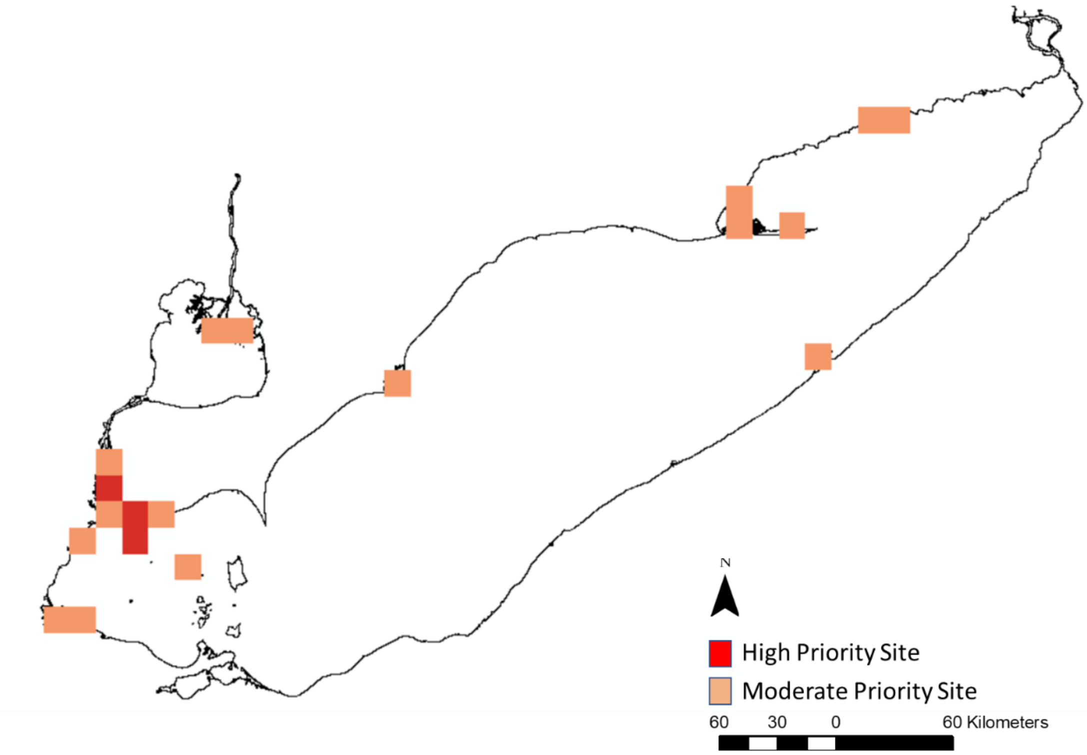

Figure 17. Lake Erie 9000mCSP$_i$ high and moderate priority sites based upon frequency of 1800mCSP values$\geq$ 1.7 in each 9000m grid. High priority and moderate priority sites classified from Jenks natural breaks optimization with frequency values ranging from 18-24 for high priority sites (n=3), and frequency values ranging from 11-17 for moderate priority sites (n=16).

Lake Ontario

For Lake Ontario, a total of nine (of 267) 9000m grids were identified as high or moderate priority sites for implementing potential management actions for ZQM control (Figure 18). A total of two high priority sites were identified in eastern Lake Ontario (Chaumont Bay and Prince Edward County NE). These high priority scores were based upon the presences of important fish spawning and nursery habitat, unionid refugia, water intake infrastructure, cladophora density, and a high threatened and endangered fish species listing index values. A total of seven moderate priority sites were identified in Lake Ontario and included the above sites as well as Amherst, Prince Edward and Big islands, Henderson Bay, and Niagara Shoal based upon presence of important fish spawning and nursery habitat, water intake infrastructure, relatively high threatened and endangered fish species listing index values, and cladophora density variously (Appendix 4). All of the high and moderate priority sites were located in eastern Lake Ontario and the Bay of Quinte, with the exception of Niagara shoal in western Lake Ontario.

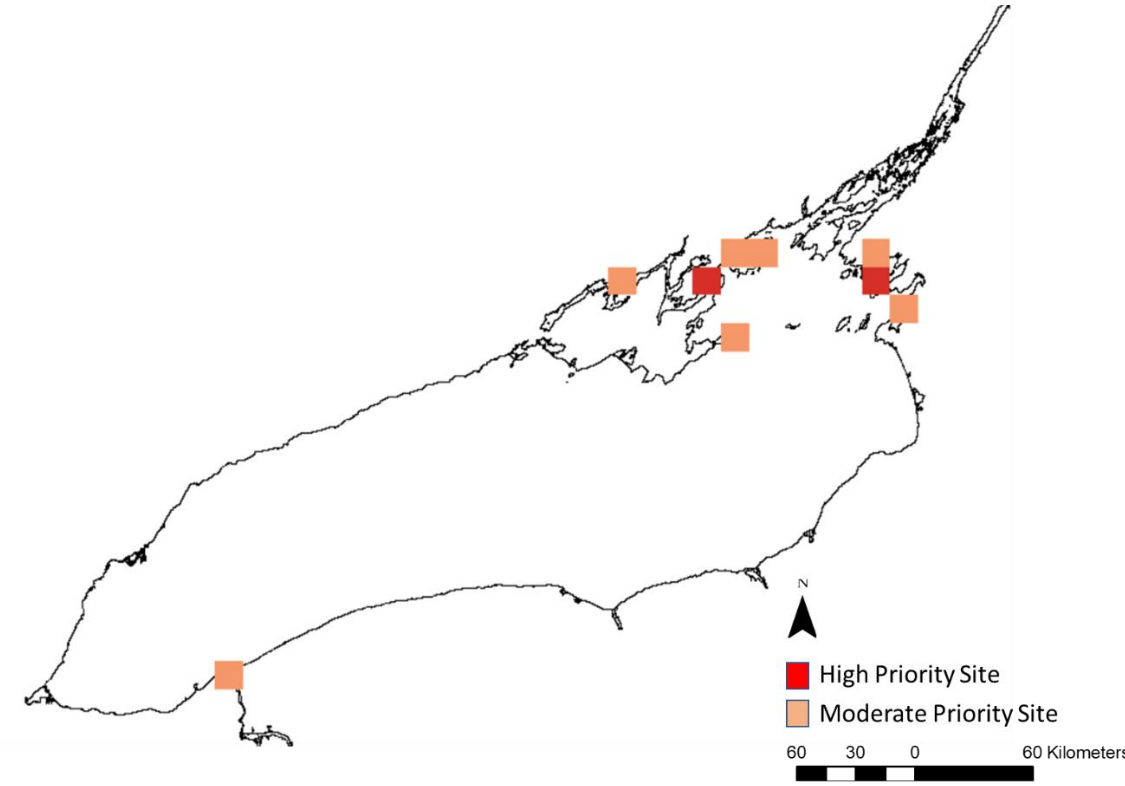

Figure 18. Lake Ontario 9000mCSP$_i$ high and moderate priority sites based upon frequency of 1800mCSP values$\geq$ 1.7 in each 9000m grid. High priority and moderate priority sites classified from Jenks natural breaks optimization with frequency values ranging from 13-16 for high priority sites (n=2), and frequency values ranging from 10-12 for moderate priority sites (n=7).

In addition to the above lake-specific maps of high and moderate priority sites for implementing experimental ZQM control, the original 90mCSP$_i$ data layer, as well as the individual 90m criterion layers (S_i, C_i, U_i, W_i, and T_i) are available for further refinement after screening level site selection (Figure 19).

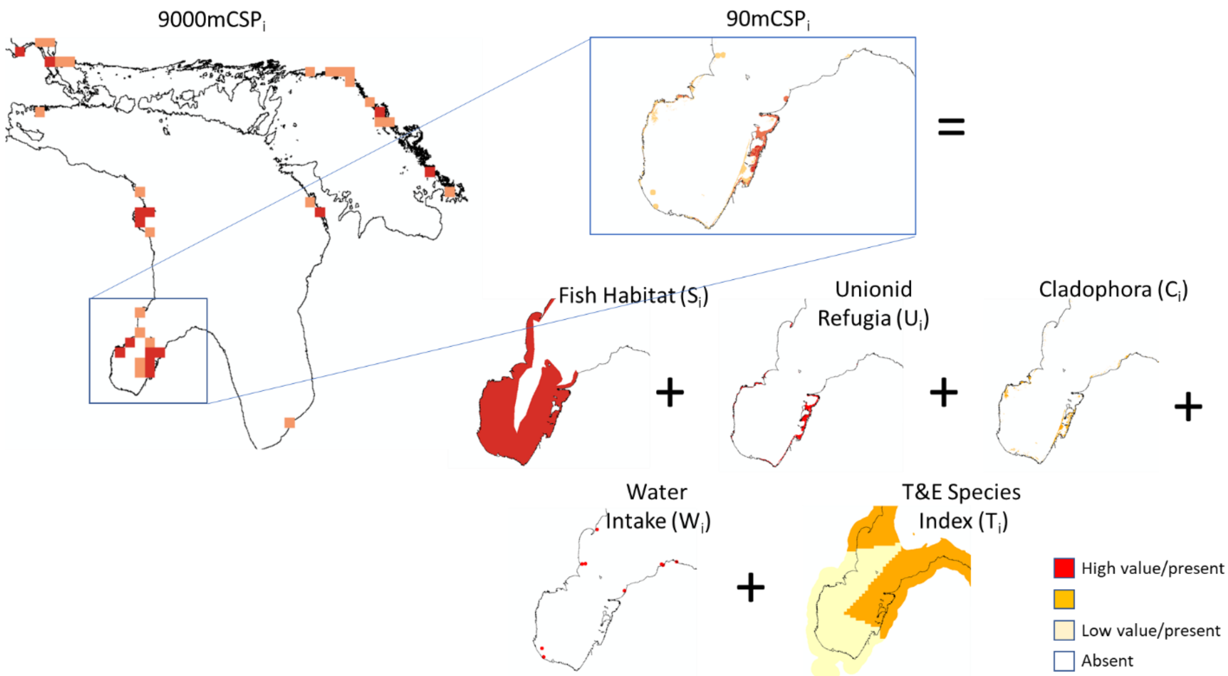

Figure 19. Example of how the $90mCSP_i$ and individual criteria can be extracted from the $9000mCSP_i$

Conclusions

In 2020, as a part of the broader Invasive Mussel Collaborative Strategy, the IMC stood up a Coastal Site Priorities Work Group, solicited for volunteers, and drafted a charge to the work group to "*review information on where dreissenids are impacting Great Lakes resources, identify criteria for evaluating sites based on this information and other considerations, and develop and implement a system for prioritizing sites for potential management activities. The outcomes will be used to inform future applied research and management activities".* The work group, comprised of nine members from state, provincial, federal, tribal, and NGO organizations met nine times over the course of 1.5 years and 1) identified five primary criteria for prioritizing coastal sites to inform future applied research and management activities, 2) identified a suite of secondary criteria for consideration after primary screening, 3) agreed upon the spatial frame, data platform, and resolution for a prioritization approach, 4) assembled and standardized basinwide, bi-national data for each of the primary criteria, 5) developed a consensus screening level prioritization approach with input from the work group, and 6) applied the prioritization approach to generate a list of prioritized candidate sites for ZQM control and restoration. The activities of the work group resulted in a prioritization process that identified 24 high priority 9000m sites and 68 moderate priority sites for consideration across the basin. The prioritization process developed by the work group is intended as a potential guide for future work, but is not intended to constrain work that has or will occur in the future at other locations based upon different criteria or these criteria applied differently. Additionally, the activities of the work group resulted in the compilation of the individual criteria layers (S_i, C_i, U_i, W_i, and T_i), the $90mCSP_i$ data layer, the $1800mCSP_i$ data layer, and the $9000mCSP_i$ data layer for potential hosting and distribution by the IMC to organizations or researchers as needed. Guidance on what products should be available to the general public, research community, or IMC members, and how the information should be hosted (static maps, geospatial layers for download etc.) would be welcome. The IMC/GLC will need to consider how to handle potentially sensitive information (e.g. water intake infrastructure), particularly at the 90m resolution if hosting the individual criteria is of value. The work group trusts that the products developed have met the needs of the IMC steering committee and the broader IMC community and that the charge has been addressed.

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Appendix 1

Invasive Mussel Collaborative

Coastal Site Priorities Work Group Charge

Final – Adopted July 30, 2020

Overview

Dreissenid mussels are widespread across the Great Lakes basin and are having a variety of impacts on coastal resources. Impacts include degrading habitat for native species, altering food web dynamics and nutrient cycling in the ecosystem, biofouling of cultural and historic resources, facilitating algal growth, and disrupting recreation, among others. To help target restoration and future management activities, the IMC Strategy includes as an objective to "Identify, evaluate, and prioritize candidate sites for ZQM control and restoration." This work group will review information on where dreissenids are impacting Great Lakes resources, identify criteria for evaluating sites based on this information and other considerations, and develop and implement a system for prioritizing sites for potential management activities. The outcomes will be used to inform future applied research and management activities.

Members

Jeff Brinsmead, Ontario Ministry of Natural Resources and Forestry
Lindsay Chadderton, The Nature Conservancy
Ashley Elgin, NOAA
Doug Kapusinski, U.S. Army Corps of Engineers
Brenda Lafrancois, National Park Service
Sarah LeSage, Michigan Dept. of Environment, Great Lakes and Energy
Erik Olsen, Grand Traverse Band of Ottawa & Chippewa Indians
Jeff Tyson, Great Lakes Fishery Commission*
Li Wang, International Joint Commission
**Indicates work group chair*

External Advisors

Nathan Barton, U.S. Fish and Wildlife Service
Dave Zanatta, Central Michigan University
TBD, Bureau of Indian Affairs
Others TBD

Objectives and Tasks

1. Develop criteria for prioritizing sites
    a. Review scope of dreissenid impacts and identify associated information that could be used to identify where impacts are occurring

    b. Identify other considerations that would inform and support the decision to implement dreissenid management activities
    c. Refine information and considerations into a list of criteria that can be used to evaluate sites
    d. Develop prioritization strategy, including consideration of whether certain criteria should be weighted
2. Compile supporting data for each of the criteria into a prioritization framework
    a. Identify available data sources and information for each of the criteria and considerations
    b. Develop a spatial reference layer using GLAHF, including defining a "coastal site"
    c. Convert the data and information into comparable datasets that can be applied to the reference layer
3. Implement the framework to apply criteria to Great Lakes coastal areas
    a. Apply criteria and prioritization to coastal sites to develop a ranked list
    b. Review output and determine priority list
4. Integrate prioritization outcomes into the IMC research agenda and associated activities to implement the IMC Strategy

Target Timeline

- Objective 1: September 2019 – July 2020
- Objective 2: July – December 2020
- Objective 3: December 2020 – April 2021
- Objective 4: April – May 2021

Site Prioritization Draft Criteria

Initially developed in discussion at September 2019 IMC meeting; subsequently revised by the work group and subject to further revision by the work group.

Primary Screening Criteria	Data Needs/Sources
Native fish spawning habitat	GLFC
Native fish nursery habitat	GLFC
Native mussel habitat/refugia	Possible approach: • Bossenbroek predictive model
TES location/habitat	Possible approaches: • NatureServe database • Compiling information from individual state/provincial natural heritage programs

Water intake infrastructure	GLC, states and provinces
Cladophora impacts to (a) recreational use and (b) waterfowl (i.e., botulism)	Michigan Tech Research Institute (ftp://ftp.mtri.org/pub/SAV_Cladophora/)

Secondary Considerations	Data Needs/Sources
Availability of long-term assessments (data/ monitoring)	
Cultural/historical sites	
Recreational usage: • Boating • Angling • Beaches	Boat ramps and marina size
Importance for focal species: • Commercial • Recreational	
Other fish habitat restoration efforts	
Treatability: • Access/proximity to marina • Depth • Exposure (e.g., current, wave action)	
Connectivity/proximity to other important habitat	
Existing/ongoing investments (e.g., collaboration, outreach, lake priorities)	
Stage of invasion; population size and status	

Appendix 2

Full Inventory of Threatened and Endangered Fish Species by Jurisdiction for Lakeshore Counties and Determination on Inclusion in Threatened and Endangered Fish Species Index (T_i)

Species	MI Status	OH Status	IN Status	ILL Status	WI Status	PA Status	NY Status	ON Status	MN Status	Included	Comments	Life History/Habitat Use/Location
Sauger	T									Y	**Lacustrine**	Lake Erie, Saginaw Bay, uncommon in Lakes Michigan, Huron, and Superior and their main tributaries (Evers 1997). In the last 20 years, the sauger has been recorded in only the St. Clair River and Lake St. Clair.
River Darter	E									Y	**Both lacustrine and riverine populations**	It is more frequently found in smaller streams during winter and spawning season in early spring. Can also be found in lakes along wave-swept shores with sand, gravel, or rubble, to depth of ~1 m (Becker 1983). Found in Lake St. Clair from 2009-2018 data
Channel Darter	E	T	E					T		Y	**Both lacustrine and riverine populations**	The channel darter inhabits rivers and large creeks in areas of moderate current over sand and gravel. The channel darter has also been reported in the nearshore waveswept areas of Lake Huron and Lake Erie in coarse-sand, fine-gravel beach and sandbar habitats (Trautman 1981).
Lake Sturgeon	T	E	E	E		E	T	T		Y		
Lake Herring	T	E		E		E				Y		
Shortjaw Cisco	T							T		Y	**Extant in Lake Superior**	
River Redhorse	T				T					Y	**Capture in Bay of Quinte, Lake Ontario**	Great lake, littoral, benthic;
Pugnose Shiner	E				T		E	T		Y	**Coastal wetlands of Lake Erie**	Inhabits slow water areas of large streams and lakes. Has been found in Cayuga Lake, Irondequoit Bay, currently found in St. Lawrence River, Sodus Bay., Lake Ontario.
Pugnose Minnow	E	E								Y	**Largely a riverine species in Ontario, but known from the Detroit River/L. St. Clair**	The pugnose minnow occurs in slow, clear, vegetated waters of rivers and shallow areas of lakes. Great Lake, littoral, midwater main stream, pools, rivers etc
Longnose Sucker		E		T		E				Y		Large lakes and Rivers
Spotted Gar		E				E		E		Y	**Personal observation at Point Pelee National Park (Lake Erie)**	Lake Erie and Historical records indicate the spotted gar resided in the Thames and Sydenham Rivers in Ontario, Canada. Habitats for spotted gar are clear, slow-moving, shallow waters of creeks, rivers, and lakes. Observed in Lake Erie
Western Banded Killifish		E		T						Y	**Banded Killifish is well known from lakes and streams in Ontario, including the Great Lakes;**	Recorded in Lake Erie in 2017. "Inhabits shallow, quiet margins of lakes, ponds and sluggish streams
Blackchin Shiner				T		E				Y	**Known from all 4 ontario great lakes**	Currently they are frequently found in the lakes and streams of the St. Lawrence watershed and bays of eastern Lake Ontario. Are currently absent or declining (Lake Erie, Allegheny, and Upper Hudson), as well as the bays and creeks off the southern shore of Lake Ontario (Carlson 1998, 2005). Blackchin shiners can be found in cool, clear, and shallow sections of lakes and slow regions of streams (Smith 1985; Page and Burr 1991). Blackchin Shiner lives in near shore areas of lakes and streams --NY State Map Distribution Record
Starhead Topminnow					E					Y		Inhabits lacial lakes and clear, well-vegetated floodplain lakes, swamps and marshes. Prefer quiet, clear to slightly turbid (cloudy), shallow backwaters. In WI, Wisconsin River between Spring Green and Sauk City, lower Sugar River and Coon Creek of the Rock River Drainage, Mukwonago River in Fox River basin, and Black River near LaCrosse.
Northern Madtom						E		E		Y	**L. St. Clair and tribs;**	Inhabits clear to turbid water of large creeks to big rivers with moderate to swift current. It has also been found in lakes, usually close to a river source with a noticeable currentIn 1994 and 1996, it was found in the St. Clair River and in Lake St. Clair, respectively. However, it had not been found downstream in the Detroit River since 1978. We report catches of 304 NOM from 2003 to 2011.
Tadpole Madtom						E				Y	**Lakes Erie, Ontario & Huron**	Inhabits pools and backwaters of sluggish creeks and small to large rivers, and in shallow areas of lakes. The tadpole madtom lives in areas with little to no current. They typically inhabit swamps and marshes, as well as lakes and slow moving streams and rivers. They also prefer habitats with turbid water; a soft mud, sand or gravel bottom
Blacknose Shiner						E				Y		In New York, it has been recorded from the Allegheny, Erie, Ontario and St. Lawrence drainages and from the Finger Lakes, Upper Mohawk and Susquehanna-Chemung watersheds. Inhabits small creeks and in the weedy shallows of lakes and ponds. NY Biological Survey of the 1930's reported females in spawning condition from the Niagara River in late July. The blacknose shiner also occurs in the shallower areas of lakes with aquatic vegetation. They occupy watersheds in the north and west parts of the state including the Allegheny River, Black River, Chemung River, Lake Champlain, Lake Erie, Lake Ontario, Mohawk River, Oswegatchie River, Oswego River, Raquette River, St. Lawrence River, Susquehanna River, and Upper Hudson River. Their primary range in New York is the periphery of the Adirondacks, western New York, and the southern tier. Historically, they were found in the Genesee River watershed but are now thought to be absent from that area.
Warmouth						E		E		Y	**Fund in Ontario waters of Lake Erie**	Are found throughout the southern Great Lakes region, but not usually abundant in any given place. Prefer habitats with little to no current, like ponds, lakes, and backwaters of streams. This species has a very restricted Canadian distribution, existing only at 4 locations along the Lake Erie shore between Point Pelee and Long Point.
Bigmouth Buffalo						E				Y	**Native to Lake Erie**	This species is established in the Lake Michigan, Lake St. Clair, Michigan and Lake Erie (Cudmore-Vokey and Crossman 2000; Bailey et al 2004). Bigmouth buffalo have also invaded Ontario through Lake Erie (Scott and Crossman 1998, Cudmore-Vokey and Crossman 2000) – first collected in Canadian waters of Lake Erie in 1957 (Scott 1957b).
Iowa Darter						E				Y	**Common in Ontario**	Native range is St. Lawrence-Great Lakes, Hudson Bay, and Mississippi River basins. Occurs in clear to lightly turbid water in small cool lakes, bogs, ponds, and in slow-moving waters of small brooks to medium rivers (Becker 1983; Propst and Carlson 1986).
Northern Redbelly Dace						E				Y	**Common in Ontario**	The northern redbelly dace has a very strong habitat preference for sluggish, spring-fed streams with a lot of vegetation and woody debris (Eddy and Surber 1974, Stasiak 1987). They can also be found in small, spring-fed lakes and bogs (Greeley and Bishop 1933, Hubbs and Cooper 1936, Das and Nelson 1990). This species may also be present in small lakes that can be characterized as spring-fed, clear, with heavy vegetation (at least along the shoreline), and few, if any, species of large predatory fishes in the littoral zone. Last observed in IL in 1965 and in OH in 1981
Mooneye							T			Y	**Present in L. Ontario and Erie**	The mooneye is found in waters from south-central Canada (Hudson Bay Basin) south though the Great Lakes Basin (except Lake Superior), the St. Lawrence River, and the Lake Champlain drainage basin. Thought to be extirpated from New York portions of Lakes Ontario, remains a modest population in Lake Champlain. There are also remnant populations in Black Lake, the Oswegatchie River, Lake Erie, the mouth of Cattaraugus Creek and the St. Lawrence River. The mooneye prefers clear water habitat of large streams, rivers, and lakes.
American Eel								E		Y	**Active recovery efforts in L. Ontario**	Established in Lake Erie drainages of Pennsylvania and Ohio. catadromous, spawning in saltwater and returning to freshwater lakes, streams, and rivers to live its adult life
Shortnose Cisco								E		Y		The only records of capture from NY are from the 1930s and 1940s. It was last recorded from a catch near Rochester in 1964 and it is regarded as extirpated. It was last seen in Lake Ontario in 1964 and in Lake Huron in 1985

Appendix 2 continued

Species	MI Status	OH Status	IN Status	ILL Status	WI Status	PA Status	NY Status	ON Status	MN Status	Included	Comments	Life History/Habitat Use/Location
Lake Chubsucker								T		Y	**Present in L. Erie**	Prefers moderately clear lakes, oxbow lakes, sloughs of weedy lakes and their associated marshy streams dense with organic debris over bottoms of cobble, sand, boulders, mud or silt. Spawning occurs from mid-May through early-July. **Occurs in counties of WI along Lake Michigan. In Ontario, the Lake Chubsucker has been captured primarily in heavily vegetated, stagnant bays, channels, ponds and swamps. In Canada, the Lake Chubsucker has been collected only in the drainages of the Niagara River, and lakes Erie, St. Clair and Huron in southwestern Ontario.
Cutlip Minnow								T		Y	**Present in the St. Lawrence River in eastern Ontario**	In Ontario, this species is at the northern extent of its range and is distributed in the lower Ottawa River and St. Lawrence River drainage areas. Recent surveys indicate that the Cutlip Minnow has disappeared from some historic sites, but new populations, low in abundance, have been found within the St. Lawrence River and surrounding tributaries. Cutlip Minnow occurs in clean gravel habitats in medium-sized streams and some lakes. It is not in western NY. It occurs in 16 watersheds. It is found only in the downstream sections in the Genesee River and Lake Ontario tributaries. **Many occurrences along Lake Ontario/tribs in NY post 1976
Silver Chub								T		Y	**Lake Erie and Lake St. Clair**	In Canada, the Great Lakes - Upper St. Lawrence populations are found in the Great Lakes basin, limited to Lake Erie and Lake St. Clair and the extreme southern portion of Lake Huron.
Brindled Madtom						T				Y	**Records for Lake Erie and Lake St. Clair (Mandrak and Crossman 1992)**	Last reported in NY waters in 1999 in the Lower Hudson, Mohawk, and Hudson-Hoosic drainages. In the Midwest, the brindled madtom is typically found in slow-moving rivers or streams primarily in pools below riffles. See Link for occurances by county and year in MI through 2010. Ontario distribution: Sydenham River, Lake St. Clair, Thames River, Lake Erie (Long Point, Turkey Point, Wheatley Harbour), Grand River, Niagara River
Eastern Sand Darter	T					E	T	E		Y	**Both riverine and lacustrine records**	It occurs in Lake Erie and its tributaries. Mostly restricted to moderate-sized streams with clean sandy bottoms; detections since 1970 in Lake Erie (Rondeau, Long Point). In Ontario, the Eastern Sand Darter is found in Lake St. Clair, Lake Erie, West Lake, Big Creek and in the Grand, Sydenham, Thames and Detroit rivers.
Greater Redhorse		T	E							Y	**Mostly riverine, but some lacustine records near river mouths (a few Great Lakes records)**	Inhabitants of medium to large-sized (50-150 feet wide) rivers, and large lakes or river reservoirs (Becker 1983). A benthic invertivore primarily found in medium to large-sized rivers and occasionally lakes
Longear Sunfish					T					Y		Introduced to mostly streams, headwaters, but also lakes of the Great Lakes and MS watersheds. Resided within the Lake Huron watershed (Cheboygan). Last observed there in 1939, last observed in Thornapple HUC8 in 1980
Southern Redbelly Dace	E					T				N	**Not present in Ontario; riverine species**	Found in small, clear, freshwater streams that are cool in temperature with a moderate to slow current. live in stream banks or headwater streams.
Redside Dace	E		E					E		N	**Riverine species**	The Redside dace is found in pools and slow-moving areas of small streams and headwaters with a gravel bottom. Spawn in shallow streams. In Canada, found in a few tributaries of Lake Huron, in streams flowing into western Lake Ontario, the Holland River (which flows into Lake Simcoe), and Irvine Creek of the Grand River system (which flows into Lake Erie).
Creek Chubsucker	E									N	**Not present in Ontario; riverine species**	Prefers pools of headwaters, creeks, small rivers
Silver Shiner	E							T		N	**Riverine species**	Found in tribs of Lakes St. Clair (thames R.), Erie (Grand R.), and Onatrio (Bronte Creek). Primarily in large streams
Bigmouth Shiner		T								N	**Not present in Ontario; riverine species**	**USGS notes it as non-indigenous. Generally, prefer living in shallow, swift moving streams. However, they inhabit shallow pools of headwaters or small to medium sized rivers with sandy substrates.
Northern Brook Lamprey			E			E				N	**Riverine species**	Lives in the eastern US in the upper Mississippi and southern Hudson Bay drainages, ranging from Manitoba and the Great Lakes region south to Missouri, and east to the St. Lawrence River in Quebec. In Ontario, it lives in rivers draining into Lakes Superior, Huron and Erie, and the Ottawa River. cataloging of this species in Michigan found it less common in small stream
Pallid Shiner			E							N	**Not present in Ontario; riverine species**	Medium to large rivers and streams, often at the end of sand and gravel bars. Primarily found over sand and mud in shallow, slow-moving, moderately clear, warm and well-oxygenated waters in impoundments with little or no current.
Gilt Darter			E		T						**Not present in Ontario; riverine species**	Prefer the moderate to fast, deep riffles and pools of clear, medium- to large-sized streams. 2010 where an individual Gilt Darter was caught at the Ohio River.Their habitat preference is clear, fast to moderate-flowing riffles or clean pools in a river.
Variegate Darter			E							N	**Not present in Ontario; appears to be a riverine species**	small rivers and streams
Redfin Shiner					T	E				N	**Riverine species**	it is present in tributaries along the Lake Erie and Lake Ontario Plains. It has preference for streams with moderate or low gradient. lives in small to medium-sized streams in a variety of ecological settings
Striped Shiner					E					N	**Riverine species, but present in connecting channels of Great Lakes (St. Clair, Detroit, and Niagara Rivers)**	In Wisconsin - In the mid-1990s all of the known locations were re-surveyed and only one individual in the lower Milwaukee River was found. Subsequent surveys of the Milwaukee River site in the 2000s did not relocate any individuals. Additional targeted surveys are needed to determine if the species has become extirpated from the state.
Ozark Minnow					T					N	**Not a Great Lakes species; riverine species**	Prefer clear, small-to-medium-sized streams with slow current and devoid of vegetation. Often seen in protected backwaters near riffles or in pools immediately below riffles where the current slackens and bottom is gravel or rubble.
Mountain Madtom						E				N		Found in fast-flowing clear riffles that are shallow generally headwater streams. Last observed in NY in 2011 and PA in 1985.
Hornyhead Chub						E				N	**Riverine species**	According to Steiner (2000) it is found in the Erie, Ohio, Susquehanna, and Delaware watersheds in Pennsylvania. Generally found in a small to medium sized gravel rivers of low to moderate gradient, cool to warm water that is typically clear.
Skipjack Herring					E					N	**Not in Ontario; appears to be a riverine species; USGS indicates not native to Great Lakes**	Prefer clear, fast waters over sand and gravel in large rivers. are strongly migratory within rivers and prefer fast flowing water where they are renowned for leaping. **The skipjack is nearly extirpated from Wisconsin, along with the ebony shell (Fusconaia ebena) and elephant ear (Elliptio crassidens), both state endangered mussels for which the skipjack is the sole host. The herring likely gained access to Lake Michigan via the Chicago Shipping Canal (Fago 1993). The report of skipjack herring from Lake Erie was rejected by Trautman (1981).
Black Redhorse								T		N	**Riverine species**	Occurs in the southern Great Lakes basin and in southeastern Minnesota, Iowa , Missouri, Oklahoma, and Arkansas. In New York, this fish has been found in both the Lake Ontario (likely extirpated) and Lake Erie drainage basins and in the Allegheny River. Most recent catches come from the Allegheny River basin and the Buffalo River.
Siskiwit Cisco	T									N		Found in Siskiwit Lake, Isle Royale; may be a subspecies of zenithicus; not detected since 1966
Ives Lake Cisco	T									N		Documented in Ives Lake, MI only (1983); some disagreement on whether distinct from C. artedi

Appendix 3

Screened Threatened and Endangered Fish Species Index Values (T_i) by Jurisdiction and County. Number listed includes both threatened and endangered species.

Jurisdiction	County Name	Number_listed	Number_Endangered	Index_value	Standardized _value (T_i)
Michigan	Alcona County	3	1	4	0.31
Michigan	Alger County	3	0	3	0.23
Michigan	Allegan County	3	0	3	0.23
Michigan	Alpena County	5	2	7	0.54
Michigan	Antrim County	1	0	1	0.08
Michigan	Arenac County	1	1	2	0.15
Michigan	Baraga County	3	0	3	0.23
Michigan	Bay County	1	0	1	0.08
Michigan	Benzie County	1	0	1	0.08
Michigan	Berrien County	4	0	4	0.31
Michigan	Charlevoix County	1	0	1	0.08
Michigan	Cheboygan County	4	2	6	0.46
Michigan	Chippewa County	3	0	3	0.23
Michigan	Delta County	2	0	2	0.15
Michigan	Emmet County	2	0	2	0.15
Michigan	Gogebic County	1	0	1	0.08
Michigan	Grand Traverse County	1	0	1	0.08
Michigan	Houghton County	4	0	4	0.31
Michigan	Huron County	5	2	7	0.54
Michigan	Iosco County	6	2	8	0.62
Michigan	Keweenaw County	2	0	2	0.15
Michigan	Leelanau County	2	1	3	0.23
Michigan	Luce County	2	0	2	0.15
Michigan	Mackinac County	3	0	3	0.23
Michigan	Macomb County	5	3	8	0.62
Michigan	Manistee County	4	1	5	0.38
Michigan	Marquette County	2	0	2	0.15
Michigan	Mason County	0	0	0	0.00
Michigan	Menominee County	2	0	2	0.15
Michigan	Monroe County	5	3	8	0.62
Michigan	Muskegon County	1	0	1	0.08
Michigan	Oceana County	0	0	0	0.00
Michigan	Ontonagon County	2	0	2	0.15
Michigan	Ottawa County	4	0	4	0.31
Michigan	Presque Isle County	4	0	4	0.31
Michigan	Saginaw County	1	1	2	0.15
Michigan	Sanilac County	1	0	1	0.08
Michigan	Schoolcraft County	3	0	3	0.23
Michigan	St. Clair County	6	1	7	0.54
Michigan	Tuscola County	2	2	4	0.31
Michigan	Van Buren County	3	1	4	0.31
Michigan	Wayne County	8	3	11	0.85
Ohio	Ashtabula County	1	0	1	0.08
Ohio	Cuyahoga County	1	0	1	0.08
Ohio	Lake County	1	1	2	0.15
Ohio	Lorain County	2	1	3	0.23
Ohio	Sandusky County	2	1	3	0.23
Ohio	Erie County	4	3	7	0.54
Ohio	Lucas County	4	2	6	0.46
Ohio	Ottawa County	4	3	7	0.54

Appendix 3 continued

Jurisdiction	County Name	Number_listed	Number_Endangered	Index_value	Standardized _value (T_i)
Indiana	LaPorte County	3	3	6	0.46
Indiana	Lake County	2	2	4	0.31
Indiana	Porter County	1	1	2	0.15
Illinois	Cook County	3	1	4	0.31
Illinois	Lake County	4	2	6	0.46
Wisconsin	Ashland County	0	0	0	0.00
Wisconsin	Bayfield County	1	0	1	0.08
Wisconsin	Brown County	1	0	1	0.08
Wisconsin	Door County	1	1	2	0.15
Wisconsin	Douglas County	1	0	1	0.08
Wisconsin	Iron County	1	0	1	0.08
Wisconsin	Oconto County	1	0	1	0.08
Wisconsin	Kewaunee County	2	0	2	0.15
Wisconsin	Manitowoc County	0	0	0	0.00
Wisconsin	Marinette County	0	0	0	0.00
Wisconsin	Milwaukee County	2	1	3	0.23
Wisconsin	Ozaukee County	2	1	3	0.23
Wisconsin	Sheboygan County	2	1	3	0.23
Wisconsin	Kenosha County	5	2	7	0.54
Wisconsin	Racine County	5	2	7	0.54
Pennsylvania	Erie County	14	13	27	1.00
New York	Niagara County	1	0	1	0.08
New York	Orleans County	1	0	1	0.08
New York	Oswego County	1	0	1	0.08
New York	Cayuga County	0	0	0	0.00
New York	Chautauqua County	2	0	2	0.15
New York	Jefferson County	2	1	3	0.23
New York	Monroe County	2	0	2	0.15
New York	Wayne County	2	1	3	0.23
New York	Erie County	3	0	3	0.23
Ontario	GREY	1	0	1	0.08
Ontario	HAMILTON-WENTWORTH	1	1	2	0.15
Ontario	MANITOULIN	1	0	1	0.08
Ontario	MUSKOKA	1	0	1	0.08
Ontario	PARRY SOUND	1	0	1	0.08
Ontario	SIMCOE	1	0	1	0.08
Ontario	SUDBURY	1	0	1	0.08
Ontario	ALGOMA	2	0	2	0.15
Ontario	DURHAM	2	1	3	0.23
Ontario	NORTHUMBERLAND	2	1	3	0.23
Ontario	THUNDER BAY	2	0	2	0.15
Ontario	TORONTO	2	1	3	0.23
Ontario	BRUCE	3	1	4	0.31
Ontario	ELGIN	3	1	4	0.31
Ontario	FRONTENAC	3	1	4	0.31
Ontario	HALTON	3	2	5	0.38
Ontario	HURON	3	0	3	0.23
Ontario	LENNOX & ADDINGTON	3	2	5	0.38
Ontario	NIAGARA	3	1	4	0.31
Ontario	PEEL	3	2	5	0.38

Appendix 3 continued

Jurisdiction	County Name	Number_listed	Number_Endangered	Index_value	Standardized _value (T_i)
Ontario	HASTINGS	**4**	**1**	**5**	0.38
Ontario	LEEDS & GRENVILLE	**4**	**1**	**5**	0.38
Ontario	Prince Edward	**5**	**3**	**8**	0.62
Ontario	HALDIMAND-NORFOLK	**7**	**2**	**9**	0.69
Ontario	LAMBTON	**7**	**2**	**9**	0.69
Ontario	CHATHAM-KENT	**8**	**4**	**12**	0.92
Ontario	ESSEX	**9**	**4**	**13**	1.00
Minnesota	Cook County	**0**	**0**	**0**	0.00
Minnesota	Lake County	**0**	**0**	**0**	0.00
Minnesota	St. Louis County	**0**	**0**	**0**	0.00
Minnesota	Carlton County	**0**	**0**	**0**	0.00

Appendix 4 – Priority site attribute tables which include site location, priority score and individual criteria index values. Individual criteria index values indicate the contribution of each primary criteria to the overall 9000mCSP$_i$ scores

Lake Superior

9000m Grid	9000m CSP$_i$	Sub Basin	Site	Priority	Fish Habitat Index	Unionid Index	Water Intake Index	Threatened and Endangered Fish Index	Cladophora Index
9526	17	Whitefish Bay	Gros Cap	High	1744	1034	0	1360	284.5
4769	11	Central Lake Superior	Black Bay	Moderate	2357	1846	0	880	0
4768	9	Central Lake Superior	Black Bay	Moderate	986	340	0	720	0
4512	9	Central Lake Superior	Thunder Bay	Moderate	704	235	0	718	2
5275	8	Central Lake Superior	Nipigon Bay	Moderate	1541	825	0	640	0
5147	7	Central Lake Superior	Nipigon Bay	Moderate	289	587	385	560	0

Lake Michigan

9000m Grid	9000m CSP$_i$	Sub Basin	Site	Priority	Fish Habitat Index	Unionid Index	Water Intake Index	Threatened and Endangered Fish Index	Cladophora Index
8639	24	Northern Lake Michigan	Hog Garden Island	High	6881	312	0	960.0	2076.5
7232	23	Green Bay	Big Bay de Noc	High	9065	32	0	1840.0	808.5
8767	19	Northern Lake Michigan	Hog Garden Island	High	5003	181	0	760.0	2318.5
6984	18	North Central Lake Michigan	North Moonlight Bay	High	2699	354	0	1440.0	1499.5
8393	17	North Central Lake Michigan	Good Harbor Reef	High	5151	0	0	1201.2	1131.5
7359	15	Green Bay	Big Bay de Noc	Moderate	4138	612	0	1200.0	152.5
9151	15	Northern Lake Michigan	Sturgeon Bay	Moderate	2266	175	0	1200.0	1777
7105	14	Green Bay	Big Bay de Noc	Moderate	4213	56	0	1120.0	204.5
7360	13	Green Bay	Big Bay de Noc	Moderate	3536	580	0	1040.0	85.5
8381	13	Northern Lake Michigan	Naubinway	Moderate	2856	3	0	1040.0	877
8511	12	Northern Lake Michigan	Hog Garden Island	Moderate	2108	106	0	480.0	853

9000m Grid	9000m CSP_i	Sub Basin	Site	Priority	Fish Habitat Index	Unionid Index	Water Intake Index	Threatened and Endangered Fish Index	Cladophora Index
6978	12	Green Bay	Big Bay de Noc	Moderate	3869	4	0	960.0	1081
6985	12	North Central Lake Michigan	North Moonlight Bay	Moderate	1523	243	0	960.0	717.5
8508	12	Northern Lake Michigan	Naubinway	Moderate	3256	0	0	960.0	304
6975	12	Green Bay	Little Bay de Noc	Moderate	2227	662	0	960.0	0
6848	12	Green Bay	Little Bay de Noc	Moderate	2945	356	111	960.0	227
7233	11	Green Bay	Big Bay de Noc	Moderate	4001	15	61	880.0	188.5
6849	11	Green Bay	Little Bay de Noc	Moderate	2756	588	389	880.0	155.5
6850	11	Green Bay	Little Bay de Noc	Moderate	3116	50	0	841.4	476.5
9279	10	Northern Lake Michigan	Sturgeon Bay	Moderate	710	15	0	800.0	350.5
9277	10	Northern Lake Michigan	Point aux Chenes	Moderate	1438	21	0	800.0	583

Lake Huron

9000m Grid	9000m CSP_i	Sub Basin	Site	Priority	Fish Habitat Index	Unionid Index	Water Intake Index	Threatened and Endangered Fish Index	Cladophora Index
11220	25	Saginaw Bay	South Saginaw Bay	High	9904	87	0	5000	1632
11221	25	Saginaw Bay	South Saginaw Bay	High	8515	1356	0	5000	2141.5
11222	23	Saginaw Bay	South Saginaw Bay	High	8355	1479	0	3880	2514.5
14140	22	North Channel and Georgian Bay	Lookout Island	High	4778	1508	0	880	16.5
11348	21	Saginaw Bay	South Saginaw Bay	High	6225	887	0	4200	2107.5
11206	21	Central Lake Huron	Thunder Bay	High	6147	251	0	4200	1362
11078	19	Central Lake Huron	Thunder Bay	High	5644	165	18	3800	455.5

9000m Grid	9000m CSP$_i$	Sub Basin	Site	Priority	Fish Habitat Index	Unionid Index	Water Intake Index	Threatened and Endangered Fish Index	Cladophora Index
11079	19	Central Lake Huron	Thunder Bay	High	6378	10	0	3800	1464
9911	19	St. Marys River	Lake Nicolet	High	0	2263	0	1520	203
13382	19	Eastern Lake Huron	Fishing Islands	High	4877	64	0	2280	694.5
10963	19	Saginaw Bay	North Saginaw Bay	High	6088	501	0	1520	866
10836	18	Saginaw Bay	North Saginaw Bay	High	7188	61	0	1440	882
14786	18	North Channel and Georgian Bay	Big David Bay	High	5475	210	0	720	389
11219	17	Saginaw Bay	South Saginaw Bay	Moderate	5469	10	0	2320	913
11093	17	Saginaw Bay	South Saginaw Bay	Moderate	6316	0	0	3400	1716
13624	17	North Channel and Georgian Bay	French River	Moderate	3553	697	0	680	0
11088	17	Saginaw Bay	East Tawas	Moderate	4698	0	0	4080	472
11090	16	Saginaw Bay	North Saginaw Bay	Moderate	4629	0	769	1280	527.5
9909	16	St. Marys River	Churchville	Moderate	0	3798	240	1280	186.5
9788	16	Northern Lake Huron	Cedarville	Moderate	461	1277	0	1280	709
13253	14	Eastern Lake Huron	Fishinig Islands	Moderate	3461	16	0	1680	1041.5
13240	14	North Channel and Georgian Bay	Phillip Edward Island	Moderate	2538	754	0	560	0
13753	14	North Channel and Georgian Bay	French River	Moderate	3563	1069	0	560	0
14011	14	North Channel and Georgian Bay	Georgian Inlet	Moderate	2387	537	0	560	0
13019	14	Central Lake Huron	Kettle Point	Moderate	1681	31	388	3920	1312.5
11094	13	Saginaw Bay	South Saginaw Bay	Moderate	5200	0	0	1800	418
14141	13	North Channel and Georgian Bay	Lookout Island	Moderate	3573	1360	0	520	0

14269	13	North Channel and Georgian Bay	Lookout Island	Moderate	2821	1154	0	520	80
9000m Grid	**9000m CSP_i**	**Sub Basin**	**Site**	**Priority**	**Fish Habitat Index**	**Unionid Index**	**Water Intake Index**	**Threatened and Endangered Fish Index**	**Cladophora Index**
11208	13	Central Lake Huron	Thunder Bay	Moderate	3413	11	0	2200	392.5
13496	13	North Channel and Georgian Bay	French River	Moderate	1940	120	0	520	0
13752	13	North Channel and Georgian Bay	French River	Moderate	2253	709	0	520	0
10039	13	St. Marys River	Pine Island	Moderate	0	1746	0	1040	198
15044	13	North Channel and Georgian Bay	Beausoleil Bay	Moderate	114	1205	0	520	256.5
9781	12	St. Marys River	Churchville	Moderate	0	1344	0	960	236.5
10167	12	St. Marys River	Campment Island	Moderate	0	608	389	960	153
11076	12	Central Lake Huron	Middle Island	Moderate	3256	5	0	2196.5	618.5

Lake Erie

9000m Grid	9000m CSP_i	Sub Basin	Site	Priority	Fish Habitat Index	Unionid Index	Water Intake Index	Threatened and Endangered Fish Index	Cladophora Index
12139	24	Western Lake Erie	Essex ON	High	8661	28	0	9600.0	0
12010	21	Western Lake Erie	Detroit River	High	2688	1129	237	7360.0	0
12140	19	Western Lake Erie	Essex ON	High	6015	0	0	7600.0	0
15072	17	Central Lake Erie	Long Point Bay	Moderate	0	624	0	4760.0	2508.5
12011	16	Western Lake Erie	Essex ON	Moderate	5522	552	0	5440.0	0
12267	16	Western Lake Erie	Essex ON	Moderate	4586	0	387	6400.0	0
12516	15	Lake St. Clair	Lake St. Clair Delta	Moderate	0	864	34	4440.0	0
15461	15	Central Lake Erie	Presque Isle Bay	Moderate	0	719	693	6000.0	75

9000m Grid	9000m CSP_i	Sub Basin	Site	Priority	Fish Habitat Index	Unionid Index	Water Intake Index	Threatened and Endangered Fish Index	Cladophora Index
11759	15	Western Lake Erie	Maumee Bay	Moderate	4233	1419	0	3120.0	0
12009	14	Western Lake Erie	Detroit River	Moderate	733	3	428	4960.0	0
11884	13	Western Lake Erie	Monroe	Moderate	3915	157	642	3120.0	0
12397	13	Western Lake Erie	Hen Island	Moderate	1178	2	0	5200.0	0
15071	12	Eastern Lake Erie	Long Point Bay	Moderate	0	609	0	3360.0	747
15328	12	Central Lake Erie	Long Point Bay	Moderate	0	307	0	3360.0	216
12644	12	Lake St. Clair	Lake St. Clair Delta	Moderate	0	1844	0	3760.0	0
11887	12	Western Lake Erie	Maumee Bay	Moderate	3257	375	512	2400.0	0
13414	12	Central Lake Erie	Rondeau Bay	Moderate	0	127	0	4320.0	0
15708	11	Eastern Lake Erie	Grand River ON	Moderate	0	10	0	3080.0	438.5
15836	11	Eastern Lake Erie	Grand River ON	Moderate	0	7	391	3074.4	533

Lake Ontario

9000m Grid	9000m CSP_i	Sub Basin	Site	Priority	Fish Habitat Index	Unionid Index	Water Intake Index	Threatened and Endangered Fish Index	Cladophora Index
18504	16	Eastern Lake Ontario	Prince Edward County NE	High	768	129	311	2368.600098	297.5
19272	15	Eastern Lake Ontario	Chaumont Bay	High	1006	270	819	1200	541
18120	12	Eastern Lake Ontario	Big Island	Moderate	1417	603	324	2640	0
18634	12	Eastern Lake Ontario	Prince Edward Island	Moderate	1323	0	0	2844	412.5
18631	11	Eastern Lake Ontario	Amherst Island	Moderate	0	95	366	1496	246.5
19401	11	Eastern Lake Ontario	Henderson Bay	Moderate	0	30	1115	880	999

16342	11	Western Lake Ontario	NIagara Shoal	Moderate	3538	0	0	920	424
9000m Grid	**9000m CSP_i**	**Sub Basin**	**Site**	**Priority**	**Fish Habitat Index**	**Unionid Index**	**Water Intake Index**	**Threatened and Endangered Fish Index**	**Cladophora Index**
19271	10	Eastern Lake Ontario	Chaumont Bay	Moderate	1151	192	9	800	500
18759	10	Eastern Lake Ontario	Amherst Island	Moderate	887	28	0	1600	368