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Development of Conservation Priorities for Migratory, River-spawning Fishes in the Michigan Waters of Lake Huron

Final Report
2 March 2012

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By

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1. Introduction

Migratory river-spawning fish are very important components of Great Lakes ecosystems. Many Great Lakes conservation plans make them a focus for conservation, including the Great Lakes Fishery Commission's Environmental Objectives for Lake Huron (Liskauskas et al. 2007) and the Lake Huron Biodiversity Conservation Strategy (Franks-Taylor et al. 2010). The lack of access to spawning habitat, due primarily to dams and improperly installed road-stream crossings, puts all migratory fish species at risk, and was recognized as a key issue in the Lake Huron Environmental Objectives (Liskauskas et al. 2007). In fact, 86% of major Lake Huron tributaries are no longer connected to the lake (Gebhardt et al. 2003). In addition to dams and other barriers, migratory fish are impacted by a variety of other threats, including sedimentation from agricultural or urban land use, altered hydrology, physical habitat alteration, and invasive species (Hay-Chmielewski and Whelan 2007, Reid et al. 2008, Fielder and Baker 2004, Franks-Taylor et al. 2010). The impact of these threats is particularly evident in species such as lake sturgeon, whose low numbers warranted listing of the species as State Threatened. However, all migratory fish are impacted and these impacts are not well understood for the migratory guild as a whole. Distributions of most Great Lakes river-spawning fishes are poorly documented and most conservation assessments for migratory fish are species specific (e.g., Fielder and Baker 2004, Boase 2007). Better distributional information on migratory fishes will allow for more effective conservation of this important guild, which links the Great Lakes to our inland river systems.

Currently, investments are being made in Great Lakes tributary restoration with the use of very little information on Great Lakes migratory fish. For example, restoration priorities for dams and barriers and the award of grant funding have been based primarily on the number of river miles that can be reconnected through barrier removal or modification. While this information is important, it is insufficient without being able to answer the question, "how much habitat will be opened up for what species?" To develop the best cost-benefit analysis to prioritize barrier removal, we need not only connectivity potential, but also information on the conservation targets themselves, i.e., where are migratory fish and where could they be if habitat were available. This critical information need requires that data be assembled that determine the most important locations for Great Lakes migratory river-spawning fishes. Also, a cost-benefit analysis would need to include information on feasibility and risk from opening up habitat to invasive species. In this project, we focused on the migratory fish distribution only, with the intention that this information could be used in future cost-benefit analyses. The priorities presented here are based solely on fish, and are not intended to be the only basis to support barrier removal decisions.

2. Project objectives

This project involved eight objectives, all of which were completed and will be discussed in this final report:

1. Map existing migratory fish distributions
2. Identify priorities for conservation of existing migratory fish habitat
3. Map potential migratory fish distributions
4. Identify priorities for restoration of historic migratory fish habitat
5. Document strengths and weaknesses of such information for management of species in migratory guild
6. Hold workshop that results in peer-review of identified priorities, integration of migratory species information and increased coordination going forward, including with Ontario resource managers
7. Communication of results including a peer-review article.
8. Contribute results to Lake Huron Biodiversity Conservation Strategy implementation efforts.

The report principally focuses on objectives 1-6. We provide additional information on objectives 5 and 6 in Appendix 1 which is a proceeding of a workshop we held to address data and knowledge gaps. A draft manuscript for a peer-reviewed journal will be submitted separately, as will the GIS data created during this project.

Finally, the results of this project will be shared with Lake Huron Binational Partnership members as well as to the U.S. Fish and Wildlife Service – both of whom have a role in implementing the LHBCS.

3. Identification of river-spawning lake fish

The first step of the project was to identify which fish species make up the river-spawning lake fish of Lake Huron. To develop this list, we consulted fish biologists (Table 1), NatureServe's online species database, documents such as the Michigan Department of Natural Resources river assessments, fish life history books (Becker 1983, Trautman 1981, and Bailey et al. 2004), other literature (Lane et al. 1996, Leonardi and Gruhn 2001, Zorn and Sendek 2001, Cwalinski et al. 2006, Schrouder et al. 2009, Roseman et al. 2009), and preliminary data sources (*Michigan Fish Atlas* and *Goodyear Great Lakes Spawning Atlas*). We focused on species that have populations that depend on both Lake Huron and tributary habitat for part of their life cycle, which includes but is not limited to species that are known to have distinct seasonal spawning runs.

Through this process, we identified 28 native Lake Huron river-spawning fish (Table 2). The list includes well-known Lake Huron river-spawners like walleye, as well as some lesser-known river-spawning species like river darter, based on the consulted experts' best judgment, literature descriptions of habitat use, or distribution maps that indicate that these fish migrate between Lake Huron and its tributaries. While developing this list, it became clear that there is significant data and expertise on only a handful of native migratory species – for most species little is known about their migratory needs and habits – making continued research in this field necessary. For some species, we received conflicting information on the status of the species as a Lake Huron river-spawning species (e.g. black redhorse), so we had to make a judgment based on the most compelling evidence.

Table 1. Experts consulted to create species list.

Expert	**Position/Affiliation**
Gerald Smith	Curator Emeritus of Fishes, University of Michigan Museum of Zoology
Jeff Schaeffer	Research Fisheries Biologist, US Geological Survey
Ed Rutherford	Research Fisheries Biologist, National Oceanic and Atmospheric Administration
Dan O'Keefe	Michigan Sea Grant
Tammy Newcomb	Research Program Manager, Michigan Department of Natural Resources
Anjanette Bowen	Fisheries Biologist, US Fish and Wildlife Service
Jim Boase	Fisheries Biologist, US Fish and Wildlife Service
Andrea Ania	Fisheries Biologist, US Fish and Wildlife Service
Amy Derosier	Wildlife Action Plan Coordinator, Michigan Department of Natural Resources
Troy Zorn	Fisheries Biologist, Michigan Department of Natural Resources
Kevin Wehrly	University of Michigan
Arunas Liskauskas	Fisheries Biologist, Ontario Ministry of Natural Resources

Table 2. Working list of river-spawning lake fish of Lake Huron

Common Name	Scientific Name	Migratory Distance
Black redhorse	Moxostoma duquesnei	Moderate
Brook trout	Salvelinus fontinalis	Moderate
Burbot	Lota lota	High
Channel catfish	Ictalurus punctatus	High
Channel darter	Percina copelandi	Moderate
Freshwater drum	Aplodinotus grunniens	Moderate
Lake sturgeon	Acipenser fulvescens	High
Lake trout	Salvelinus namaycush	High
Lake whitefish	Coregonus clupeaformis	High
Longnose gar	Lepisosteus osseus	Moderate
Longnose sucker	Catostomus catostomus	Moderate
Mooneye	Hiodon tergisus	Moderate
Muskellunge	Esox masquinongy	Moderate
Northern pike	Esox lucius	Moderate
Quillback	Carpiodes cyprinus	Moderate
River darter	Percina shumardi	Moderate
Round whitefish	Prosopium cylindraceum	High
Sauger	Sander canadensis	High
Shorthead redhorse	Moxostoma macrolepidotum	Moderate
Silver lamprey	Ichthyomyzon unicuspis	Moderate
Silver redhorse	Moxostoma anisurum	Moderate
Smallmouth bass	Micropterus dolomieu	Moderate
Spottail shiner	Notropis hudsonius	Moderate
Trout-perch	Percopsis omiscomaycus	Moderate
Walleye	Sander vitreus	High
White bass	Morone chrysops	Moderate
White sucker	Catostomus commersonii	Moderate
Yellow perch	Perca flavescens	Moderate

4. Data Acquisition

We acquired data on fish distribution and, where available, abundance (number of individuals of each species) for the Lake Huron watershed (Table 3). In total, we worked with eleven sources to gather these data. Across stream datasets there were 29,866 fish collections (Figure 1), though most collections did not include any of our 28 migratory fish species (<30%). These data were originally collected for a variety of reasons and from varied sources that were gathered or organized differently. As a result, the data required substantial manipulation to assemble into a database and GIS spatial layers that could then be analyzed.

To map migratory fish, the ideal data sets would be collected during their spawning periods, and include the abundance of each species relative to the sampling effort and area sampled, and the sizes (or age class) of the fish caught. Yet as shown in Table 3, very little of the available data meets all of these criteria. Of approximately 8,500 species records in streams, 1,700 had abundance data, of which relative abundance could be calculated for 1,193 and only 363 records were recorded during the spawning period for the caught fish.

From the records we collected, we created two major categories of data: coastal and stream data. For the coastal data, we were able to use the *Michigan Fish Atlas* and *Goodyear Great Lakes Spawning Atlas* (which provided 10,800 locations of where species have been found), as well as some more focused datasets that further strengthened our coastal data, to map congregations of fish at river mouths. From these data, we were able to make reasonable assumptions about the importance of specific rivers for each species.

While we acknowledge that significant data gaps exist, we believe that there was substantial value in mapping these "best available" data comprehensively for the Lake Huron basin in the US – we will address the patterns these data revealed in greater depth later in this report.

Table 3. Data used in analysis, categorized by location and data type.

Streams	**Stream Data**	**Coastal Data**	**Presence-Absence**	**Abundance**	**Age Classes**
Aquatic Gap[1]	X		X		
DNR-Fish Collection Database[2]	X		X	X	X
DNR-Michigan Rivers Inventory[3]	X		X	X	
FWS-lamprey[4]	X		X		
DEQ (p-51)[5]	X		X	X	
CMU[6]	X		X	X	
Fish Atlas[7]	X	X	X		
Biotics[8]	X	X	X		
FWS-Bowen[9]		X	X	X	X
EPA[10]		X	X	X	X
Goodyear[11]		X	X		

[1]*Great Lakes Aquatic Gap – predicted fish distributions (USGS, unpublished)*
[2]*Michigan Department of Natural Resources, fish collection database (managers' database)* [3]*Troy Zorn, Michigan Rivers Inventory fish dataset, MDNR Fisheries Division, unpublished*
[4]*US Fish and Wildlife Service, fish assemblage data collected during larval lamprey surveys,*
[5]*Michigan Department of Environmental Quality, Procedure 51, fish assemblage data (1990-2006)*
[6]*Central Michigan University, Saginaw Bay tributary data, Tracy Galarowicz, unpublished*
[7]*Michigan Fish Atlas (Michigan Department of Natural Resources)*
(The link provided was broken and has been removed)
[8]*Biotics Element Occurrence Data, Michigan Natural Features Inventory*
[9]*US Fish and Wildlife Service, Anjanette Bowen, river mouth trawl data, unpublished.*
[10]*US Environmental Protection Agency, coastal wetland surveys, Annet Trebitz, et al.* [11]*Goodyear Fish Atlas, USGS, (The link provided was broken and has been removed)*

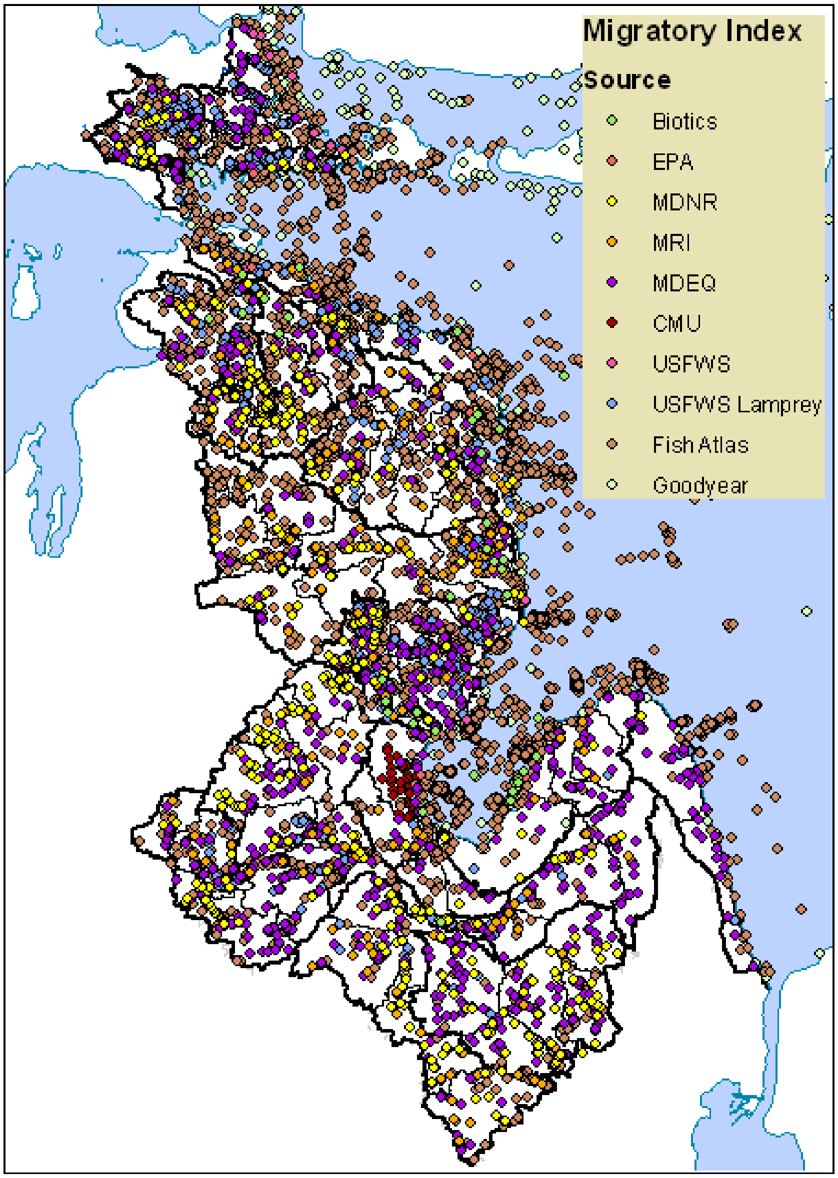


Figure 1. Sampling locations.

5. Data assembly and review by partners

The assembly of these disparate data sources involved four main steps:

- reviewing, by species, the available data;
- locating all the data to a common map of streams;
- inviting peer review of the data sets, of our completed preliminary analyses, and of additional analyses we planned to complete; and
- Addressing data gaps and questions raised about our assumptions.

Locating data to common hydrography
The second step – locating all the data to a common map of streams – was essential in order to complete a comparative analysis. To accomplish this, stream data and coastal data were handled separately. Stream points from all sources were aligned with the Aquatic Gap stream network using the near analysis tool in ArcMap 9.3. All points that were moved more than 30 m were evaluated to ensure they were within the

correct stream reach. Many sites within the MDNR-Fish Collection Database did not include spatial data. If sufficient information was available to identify the stream reach (e.g. stream name and road intersection), these sites were mapped manually, otherwise these sites were deleted. For FWS-lamprey data, many sample locations did not include a spatial reference or a description specific enough to identify the sample reach. Instead, sites were identified by a tributary number and a second value indicating where along a sequence of evenly spaced samples the data were collected. Using this information, we could infer the correct reach with sufficient confidence that when the data were summarized at a HUC10 watershed scale they should be accurate. Data for each migratory fish species—presence, abundance and young-of-year abundance, as available—were then related to each reach. Predicted locations from Aquatic Gap were already associated with each reach.

The Aquatic Gap network does not include streams located on Lake Huron islands. Therefore, island streams were not included in our analyses. This most notably omitted several streams on Drummond Island. Data sources were checked for the presence of Lake Huron migratory fishes on Drummond Island.

To relate coastal points from all sources to stream reaches, buffers were drawn around each point in ArcMap 9.3 based on the likely migratory distance for each species. We classified each species as having either a moderate or high migratory distance (Table 2). While we had identified more specific migratory distance categories from several sources (Natureserve 2011, Trautman 1981, Becker 1983), experts who reviewed our preliminary analyses felt that two general migratory distance categories were most appropriate given significant uncertainty exists for most species. Certainly individuals for many species are capable of moving further, but some limit had to be identified to provide a higher weighting to rivers in closer proximity to occurrences. We selected three different buffer distances for each point, so that tributaries with many points immediately adjacent to the mouth of that tributary would have a higher coastal point count than other nearby tributaries. These buffer sizes differed between moderate and high distance fish (Table 4). These buffers were then intersected with terminal points, the point at which each tributary enters Lake Michigan (Figure 2a) and the terminal points were given a score of "3" if within the inner buffer, "2" if within the middle buffer, and "1" if within the outermost buffer. Buffer scores for each species were then summed for each terminal point, and applied to all reaches upstream from the terminal point (Figure 2b).

Table 4. Sizes for the three different buffers drawn for moderate and high migratory distance categories, and count provided to upstream reaches when that buffer intersects a particular river mouth.

	Fish Migratory Distance		
Buffer Size	**Moderate**	**High**	**Score**
Inner buffer	5 km	10 km	3
Middle buffer	10 km	20 km	2
Outer buffer	20 km	50 km	1

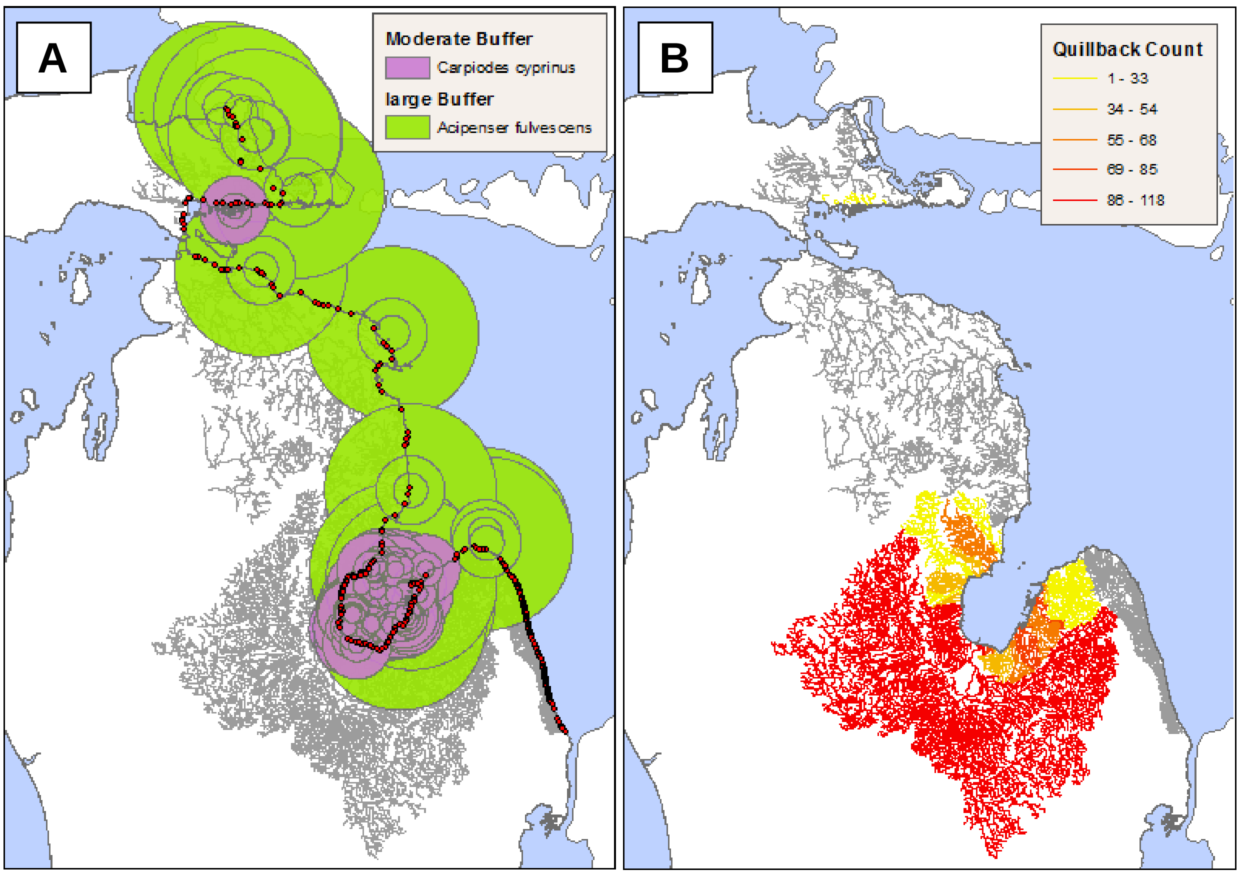


Figure 2. Example of relating coastal data to stream reaches. Map A shows terminal points for each watershed with examples of buffers for a moderate (*Carpoides cyprinus* or quillback) and large (*Acipenser fulvescens* or lake sturgeon) distance migratory fish species. Map B how the buffer count looks for quillback when applied to stream reaches.

Peer review

The final step in assembling the data was to invite peer review. On June 29, 2011 we met with Paul Seelbach (US Geological Survey – Great Lakes Science Center) and Ed Rutherford (NOAA – Great Lakes Environmental Research Laboratory), and then on June 30, 2011 with Jeff Schaeffer (U.S. Geological Survey – Great Lakes Science Center); Dave Fielder (Michigan Department of Natural Resources); and Andrea Ania, Anjanette Bowen, and Steve Lennart (from the US Fish and Wildlife Service). Those meetings included review of the species list, review of the data sets, survey of other data sources, review of methods, and review of some initial results. Based on that input, we added one data source and revised some of our classifications of fish in terms of migration distance. We also made key decisions on how to apply index calculations at the watershed scale.

6. Priority watersheds by species

Index of reach migratory importance

For each species, a migratory fish index was developed and calculated for each reach based on 5 factors:

1. number of times the species was collected from the reach
2. abundance of the species within the reach
3. abundance of young-of-year within the reach
4. predicted presence of the species within the reach
5. frequency of occurrence of the species in Lake Huron near the mouth of the river (from the coastal point count).

For each species the frequencies for reaches where the species had been collected were grouped into four classes (1-4) in ArcMap using natural breaks, while reaches where the species had not been collected were given a value of zero (0, 1-4) . For reaches where abundance data existed for each species, an average and maximum abundance was calculated. These were also mapped and grouped into four classes using natural breaks (0, 1-4). For any given reach, whichever rank was higher between the average and maximum was the rank used for the index. We did this because we felt it was important to give greater weight to samples with high abundances, which in some cases would be masked by using the average. This same approach was used for young-of-year abundance (0, 1-4). Predicted presences from aquatic gap were treated in a binary fashion (0, 1). Finally, the coastal point counts for each reach were grouped into four classes using natural breaks (0, 1-4). For each reach, an index score was calculated as the average rank across each of the five factors. In cases where the only data for a species in a particular reach came from the coastal sample buffering (i.e., there were no corroborating stream data), the reach did not receive an index score. See Table 5 for an example of the index score was calculated for one species.

Table 5. Example of calculation of index score for yellow perch at eight sampling locations. The shaded columns show the rank scores averaged to calculate the index score. In this case the ranks for the average abundance and maximum abundance were the same.

Unique ID	Gap Reach Code	Presence Frequency	Frequency Rank	Average Abundance	Abundance Rank	Maximum Abundance	Maximum Abundance Rank	Average YOY abundance	Average YOY Rank	Maximum YOY abundance	Maximum YOY Rank	Predicted by GAP	Coastal Frequency	Coastal Rank	Index Score
6041	sagin1268	23	4									1	248	4	1.8
746	ausab747	16	3	6.75	1	24	1	9	2	24	3	1	77	2	2
6032	sagin1259	14	3	50.5	1	86	1					1	248	4	1.8
1956	chebo109	13	3	6	1	12	1	12	2	12	2	1	24	1	1.6
741	ausab742	13	3	0.5		1		1	1	1	1	1	77	2	1.4
4303	rifle304	14	3	24	1	31	1					1	59	2	1.4
2941	ocque167	10	3									1	9	1	1
10166	thund90042	9	3										124	2	1

Index scores per watershed

For each species, we mapped the index scores per stream reach and then averaged those within each HUC10 watershed. Because sampling effort was highly variable among stream reaches, with some reaches never having been sampled, we decided to develop priorities for each species at a HUC 10 watershed scale (Figure 3). This scale reduces the effect of sampling variability, while still maintaining enough specificity to be meaningful for conservation purposes. Priorities for each species were developed separately across the connected reaches within each HUC10 (below lowest dam barrier) and the unconnected reaches (above lowest dam barrier). We used a connectivity layer developed by the Michigan Department of Natural Resources, Institute of Fisheries Research, obtained through the Great Lakes GIS (*The link provided was broken and has been removed*; Figure 4). Stream connectivity to Lake Huron is determined by location of dams. Road-stream crossings that serve as barriers are not reflected by this data layer.

The index scores for each connected reach were averaged within each HUC 10 and similarly for the unconnected reaches. Of the 68 total HUC 10 watersheds, 10 watersheds contain only connected reaches, 30 contain only unconnected reaches, and 28 contain both. The average index values were then mapped using ArcMap GIS, using natural breaks to identify five classes (some species had fewer classes when sufficient data variability was not available). For each species, this report includes a map of the index scores by reach, the index scores averaged for each HUC 10 across connected and unconnected reaches (Figure 5a-c). In this example, silver lamprey habitat is widely distributed, but is most strongly associated with the Cheboygan River watershed and the southern portions of the Saginaw River watershed. The unconnected maps do not address the feasibility of reconnecting the watersheds and are based only on likely presence of the species based on historic data and modeled data. The full set of maps per species can be found in Appendix 2.

In general, habitat for most species included some larger river habitat, with freshwater drum and white bass habitat being almost exclusively in larger rivers. Habitat for numerous species included significant areas of smaller, direct tributaries of the lake, including brook trout, yellow perch, northern pike, shorthead redhorse, silver redhorse, smallmouth bass, spottail shiner, and white sucker. Species with habitat strongly oriented toward northern Lake Huron were brook trout, burbot, longnose sucker, and round whitefish. Species with habitat strongly oriented toward southern Lake Huron included channel catfish, quillback and shorthead redhorse. Many species were rare across the datasets used in this analysis, including mooneye, sauger, channel darter, lake trout, lake whitefish, muskellunge, river darter, lake sturgeon, and round whitefish. Many of the migratory fish species had higher index scores in the Shiawassee Flats region, a large floodplain wetland area where five rivers converge (Cass, Flint, Shiawassee, Bad, and Tittabawassee Rivers) before forming the Saginaw River. These included silver lamprey, channel catfish, channel darter, freshwater drum, longnose gar, northern pike, quillback, river darter, shorthead redhorse, silver redhorse, spottail shiner, walleye, white bass, white sucker, and yellow perch.

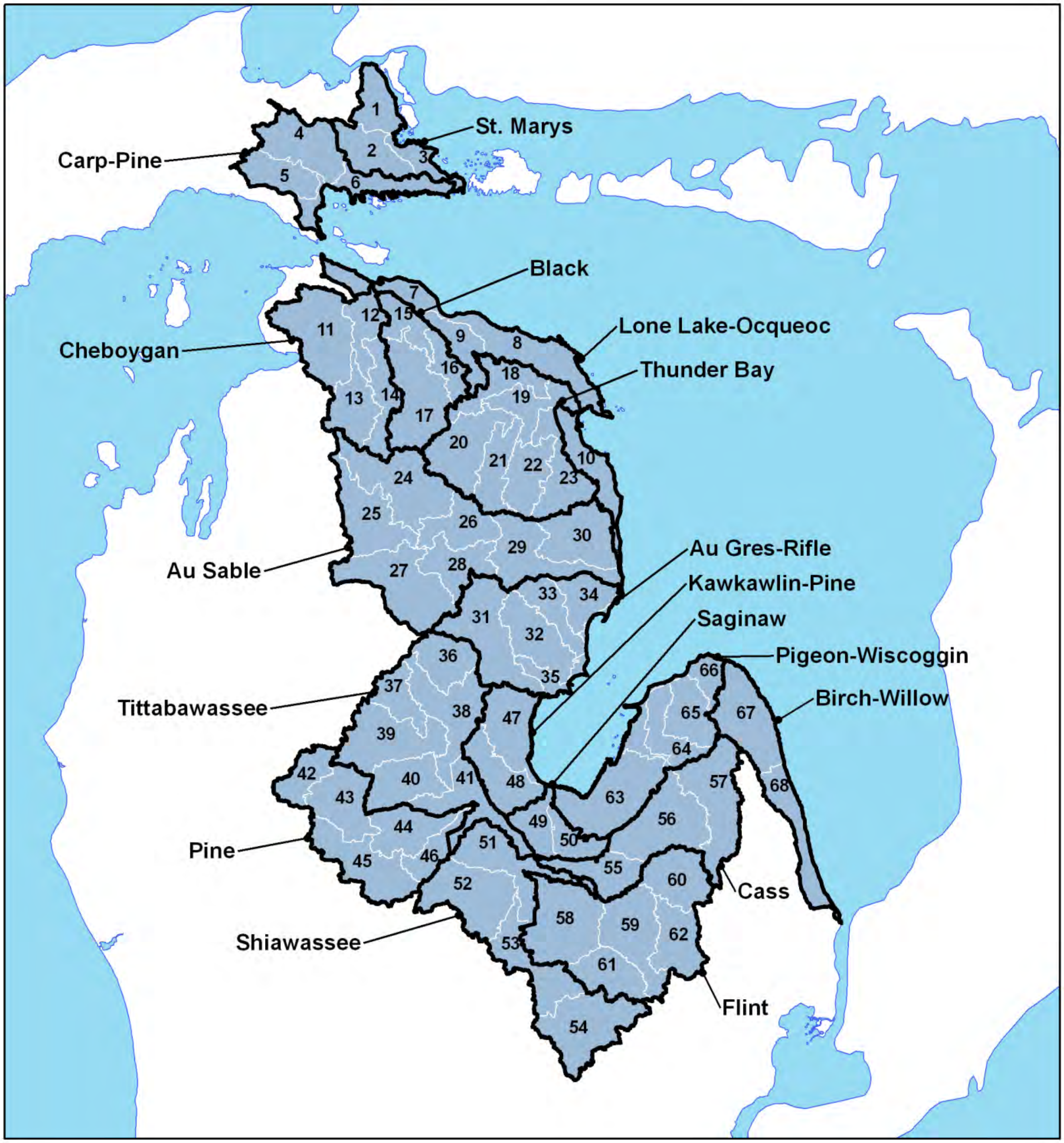


Figure 3. Reference map showing HUC8 and HUC10 units. HUC10 names are given in Table 6.

Table 6. HUC10 watershed names. See Figure 3 for accompanying map.

St. Mary's	**Tittabawassee**
1 Charlotte River – Frontal St. Mary's River	36 Headwaters Tittabawassee River
2 Munuscong River	37 Cedar River
3Gogomain River – Frontal St. Mary's River	38 Sanford Lake
Carp – Pine	39 Tobacco River
4 Pine River	40 Salt River
5 Carp River	41 Tittabawassee River
6 McKay Creek – Frontal Lake Huron	**Pine**
Lone Lake – Ocqueoc	42 West Branch Chippewa River
7 Little Black River – Frontal Lake Huron	43 Cold Water River – Chippewa River
8 Swan River – Frontal Lake Huron	44 Chippewa River
9 Ocqueoc River	45 Honeyoey Creek – Pine Creek
10 Black River – Frontal Lake Huron	46 Pine River
Cheboygan	**Kawkawlin – Pine**
11 Burt Lake	47 Pine River – Frontal Lake Huron
12 Cheboygan River	48 Kawkawlin River
13Sturgeon River	**Saginaw**
14 Pigeon River	49 Saginaw River
Black	50 Cheboyganing Creek
15 Black River	**Shiawassee**
16 Rainy River	51 Shiawassee River
17 Upper Black River	52 Bad River
Thunder Bay	53 Webb Creek
18 North Branch Thunder Bay River	54 South Branch Shiawassee River
19 Thunder Bay River	**Cass**
20 Headwaters Thunder Bay River	55 Cass River
21 Upper South Branch Thunder Bay River	56 White Creek
22 Wolf Creek	57 South Branch Cass River
23 Lower South Branch Thunder Bay River	**Flint**
Au Sable	58 Flint River
24 North Branch Au Sable River	59 North Branch Flint River
25 East Brank Au Sable River	60 North Branch Flint River
26 Perry Creek	61 Swartz Creek
27 South Branch Au Sable River	62 South Branch Flint River
28 Big Creek	**Pigeon – Wiscoggin**
29 Au Sable River	63 Sebewaing River – Frontal Lake Huron
30 Pine River	64 Pigeon River
Au Gres – Rifle	65 Pinnebog River
31 Rifle River	66 Bird Creek – Frontal Lake Huron
32 Au Gres River	**Birch – Willow**
33 East Branch Au Gres River	67 Elk Creek – Frontal Lake Huron
34 Tawas River	68 Mill Creek – Frontal Lake Huron
35 Big Creek – Frontal Lake Huron	

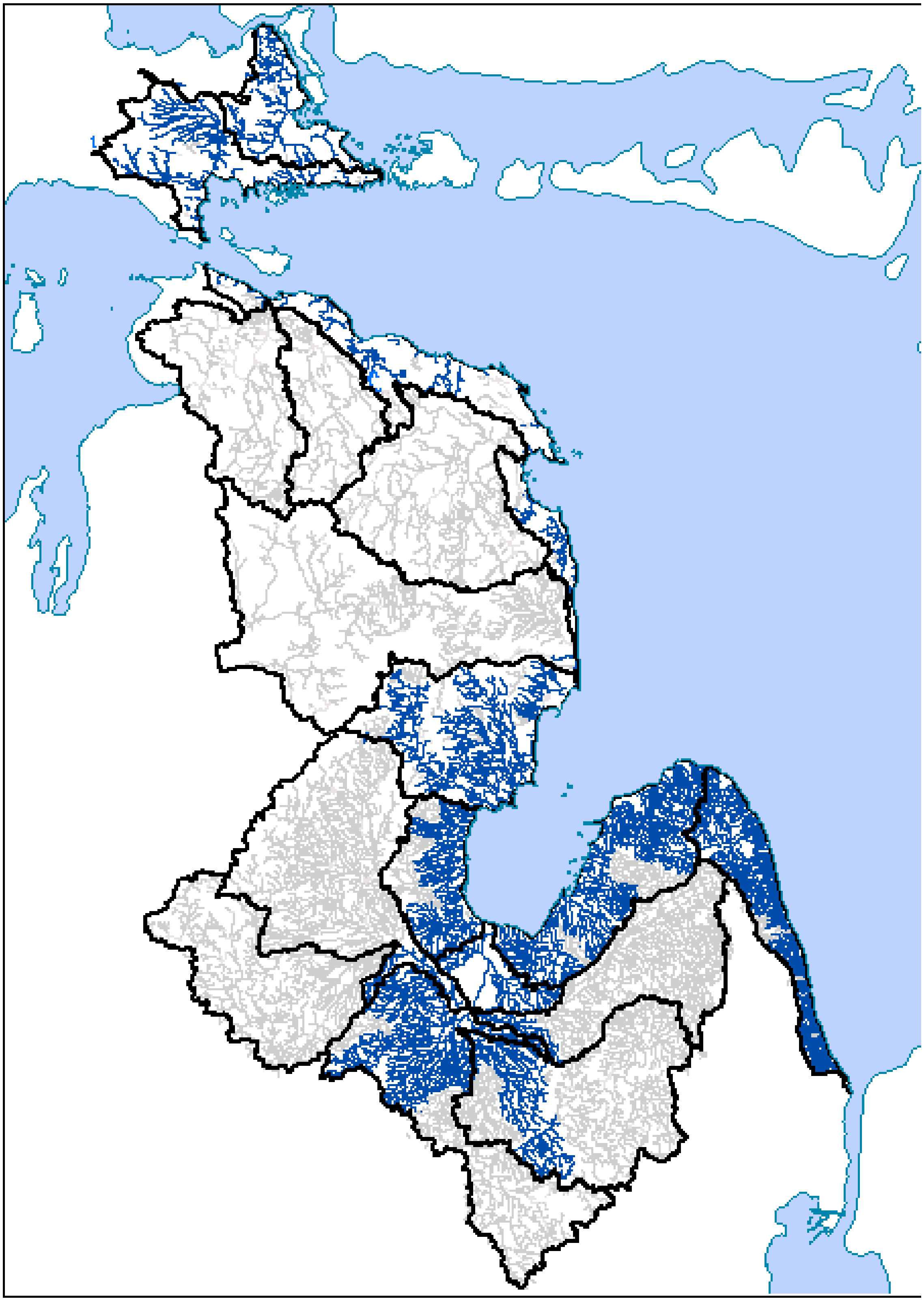


Figure 4. Stream segments in the Michigan portions of the Lake Huron Basin that are connected (below lowest dam barrier; in blue) and unconnected (above lowest dam barrier; in grey) to Lake Huron. HUC 8 watershed polygons are also shown.

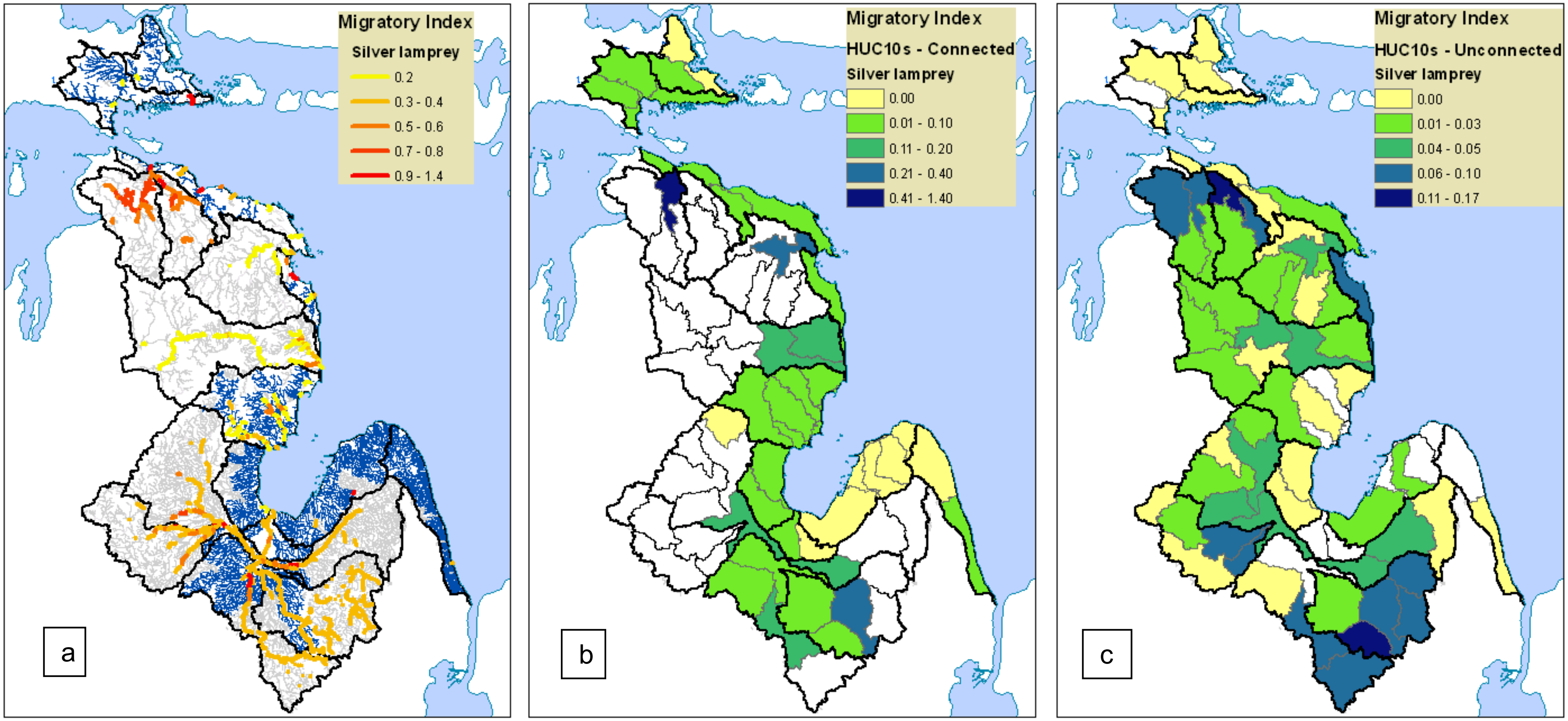


Figure 5a-c. Tributaries that analyses indicate are important to Lake Huron silver lamprey for (a) specific stream locations, (b) watersheds based on streams connected to Lake Huron, and (c) watersheds based on unconnected streams only.

Review and revision of index scores

Index maps for each species were distributed to Lake Huron fisheries biologists from the Michigan DNR and U.S. Fish and Wildlife Service. Feedback was received from seven biologists (5 DNR, 2 FWS). In general, feedback indicated that the mapping results seemed logical and accurate and would be helpful in management efforts. However, for some species, the biologists provided supplemental locations based on knowledge of the species' distribution from past sampling, other data sources, personal observations (e.g., fishing), or anecdotal information. In a few cases, their input resulted in a significant revision to the distribution maps. The reasons for making significant revisions fell into 3 categories. First, most of the datasets we used were assemblage collections and some species are generally not readily collected during this type of sampling. These include lake sturgeon, lake trout, and lake whitefish (see Figures 6a-b for examples of such changes made). Second, for species with many inland populations and few migratory populations, the inland population data can "swamp out" the migratory run data—especially if the migratory runs are not in high abundance. This was the case with brook trout, which were the only species for which most of the analyzed data were discarded. For brook trout, after consulting with our regional experts, we incorporated results from Enterline (2000), a comprehensive review and evaluation of Lake Huron brook trout runs, and discarded the inland populations. Coastal streams identified in the report were compared and combined with the data we assembled to rate coastalHUC10 watershed units (Figure 6c-d). Finally, experts felt that our indices were vastly overpredicting the distribution for a few other species (e.g. white bass, channel catfish) and upon reviewing each of the input datasets spatially we found that the Gap predicted locations seemed to be overpredicting the distribution of these species. For these species, the index scores were recalculated without Gap. Figures 6e and 6f show the difference in stream reaches with and without white bass. We approached this with care though, making sure that no historic sampling data indicated that the species had been there in the past. In each of these cases, the HUC10 index scores for the affected species were recalculated according to expert input.

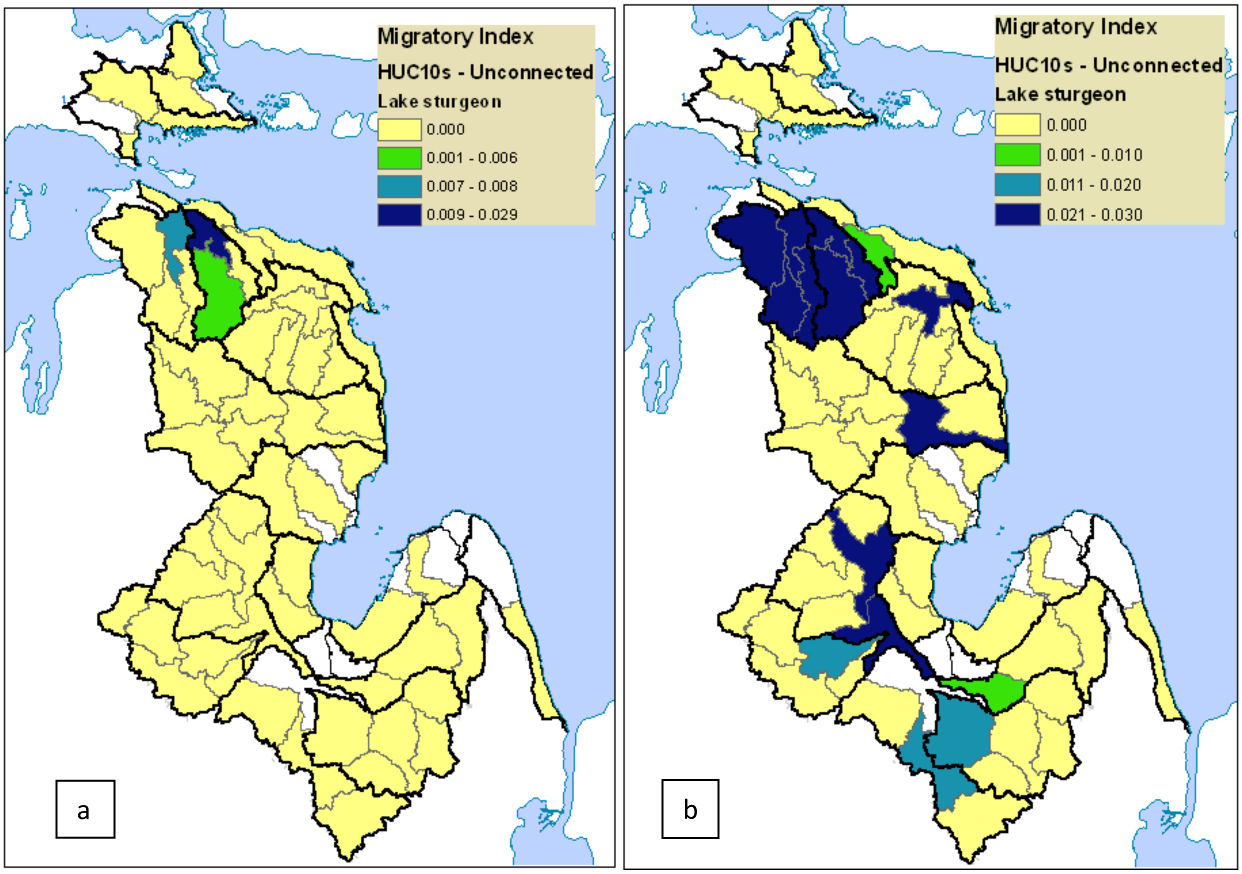


Figure 6a-b. Ranking of HUC10 watersheds for lake sturgeon based on original data sources (a) and with expert input (b). Experts recommended expanding the area of the Cheboygan River watershed, and including the Rifle River and Tittabawasee.

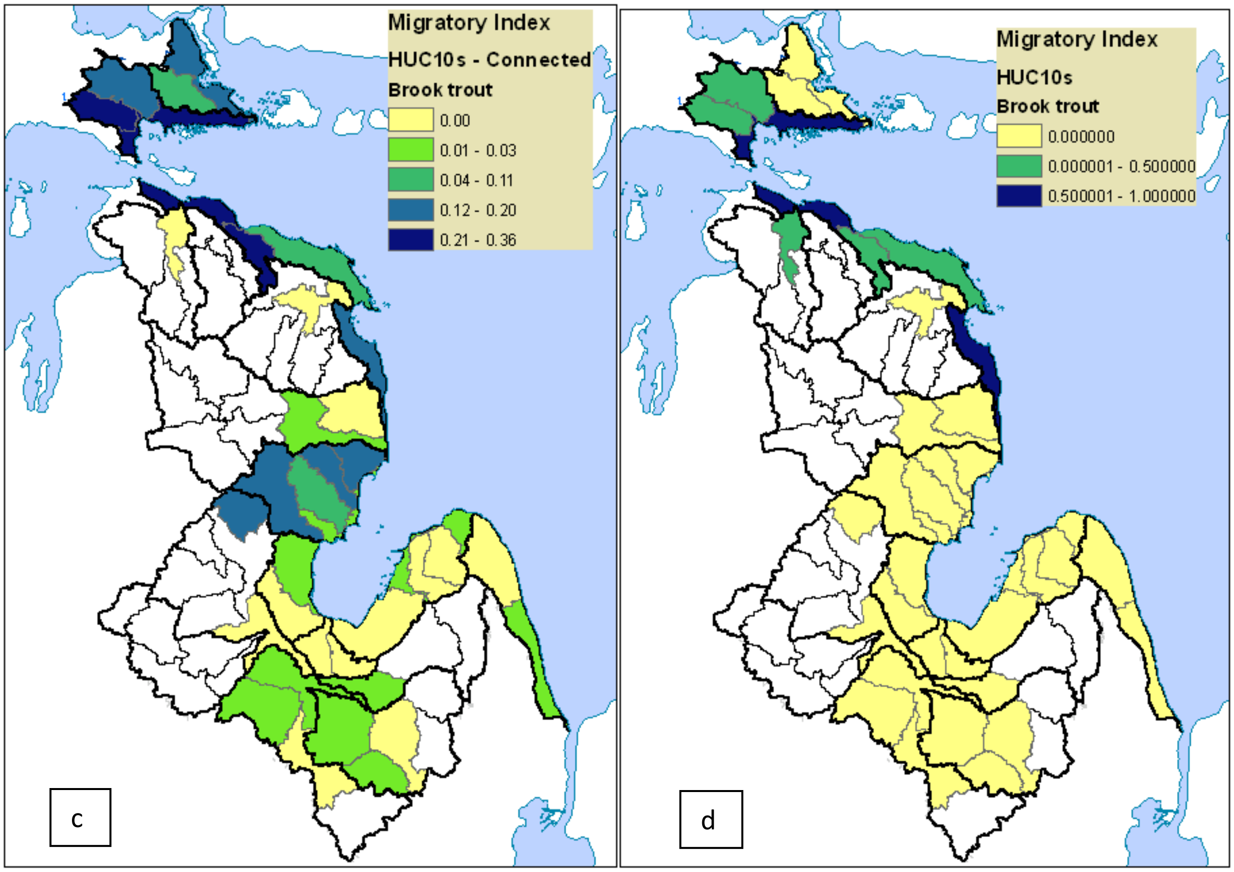


Figure 6c-d. Brook trout priority watersheds, based on connected reaches, showing change from ranking based on our original data sources (c) and based on Enterline (2000) (d). The latter limits the significant watersheds to the Upper Peninsula and northern Lower Peninsula.

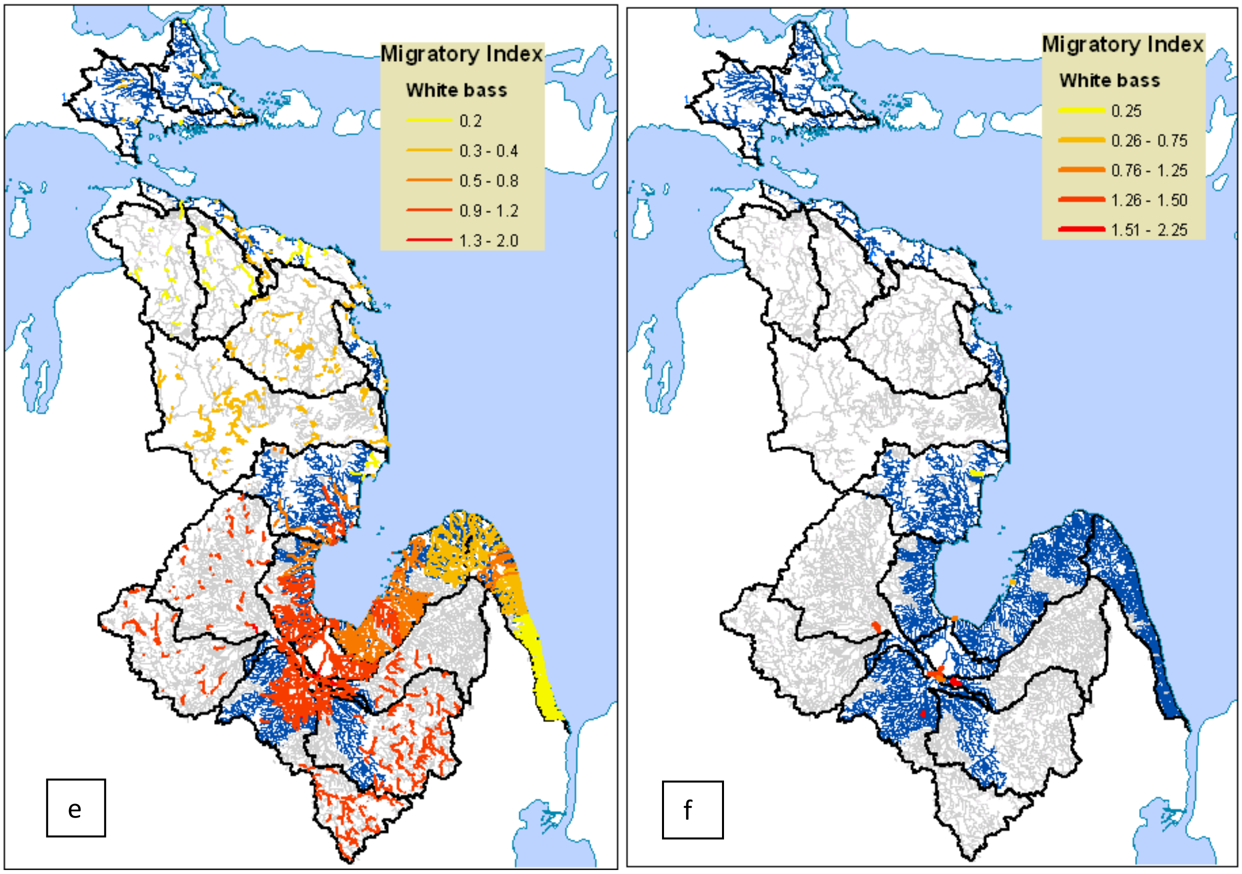


Figure 6e-f. White bass migratory index values applied to the reach scales including Gap predicted reaches (e) and without Gap predicted reaches (f). The latter shows that the significant areas are limited to the lower reaches of rivers in the Saginaw River drainage.

7. Watersheds prioritized across species

In addition to identifying key watersheds for each species, we wanted to address the question – where are the key watersheds when you consider the distributions of all native Lake Huron river-spawning lake fishes? Prior to conducting this analysis, two species were removed from the analysis. Black redhorse were removed because the datasets we assembled indicate that they are a riverine fish that does not utilize Lake Huron and experts reviewing preliminary analyses supported this conclusion. Mooneye were not included because we had no stream records for them and experts agreed that the watershed adjacent to the coastal record we obtained did not make sense as mooneye spawning habitat. To identify these watersheds of greatest migratory importance across species, we ranked the top watersheds for each species, separating the analysis for connected and unconnected reaches as described previously. We ranked the top ten, giving a value of ten to the watershed with the highest average index score for each species. Tie values were given the same rank. An example of this ranking is provided in Table 7. We then summed these rank values across all species within each watershed to calculate a score. The accompanying maps (Figures 7 and 8) show the scores for the watersheds considering connected reaches and unconnected reaches separately, as well as showing how the overall ranking changed based on the expert review described in Section 6 above.

Table 7. Example of how rank scores were calculated for each species. The top two silver redhorse scores were the same, so each watershed was given a rank of 10 and then the next highest a rank score of 8.

HUC10 Code	Silver Redhorse Index	Silver Redhorse Rank
0407000404	0.2	10
0408020404	0.2	10
0408020302	0.072727	8
0408010302	0.063158	7
0408020503	0.062222	6
0408020602	0.051429	5
0407000707	0.05	4
0408020106	0.048387	3
0408020405	0.033333	2
0408010104	0.020321	1

We evaluated how well the top scoring watersheds captured the full list of migratory species. The top ten connected reach watersheds in our original analysis captured 23 of the 26 species we analyzed, missing lake trout, lake whitefish or sauger. Lake trout were not in the connected reach watersheds. In the expert informed analysis, the top five connected watersheds captured all 26 species. In the original set of unconnected reach watersheds, the top five watersheds captured 22 of 26 species, missing drum, muskellunge, river darter and sauger. Drum is picked up in the 7th top watershed. Sauger was found in the 14th top watershed and muskellunge in the 15th. River darter is not found in the original unconnected watersheds. In the expert revised unconnected reach watersheds, the top five watersheds captured 23 of 26 species, leaving out brook trout, river darter and round whitefish. Brook trout and round whitefish are in the top 10, river darter is picked up in the 12th highest scoring watershed.

While we felt that it was important to get input from regional biologists to ensure that the results reflected their knowledge of the system, it is also important to understand whether their input fundamentally changed the priority watersheds identified in this effort. In addition to showing the priority maps before and after revisions, we conducted Spearman's rank correlations to test whether the revised maps were statistically concordant with the previous maps using JMP software. The rankings for HUC 10 watersheds were highly concordant before and after revisions for both connected (Spearman's $\rho = 0.88$; $p < 0.0001$) and unconnected reaches (Spearman's $\rho = 0.81$; $p < 0.0001$).

Drummond Island streams were not included in our analyses because they are not in the Aquatic Gap network. Our data sources show that several migratory fish species utilize Drummond Island streams, including yellow perch, white sucker, smallmouth bass, spottail shiner, and northern pike.

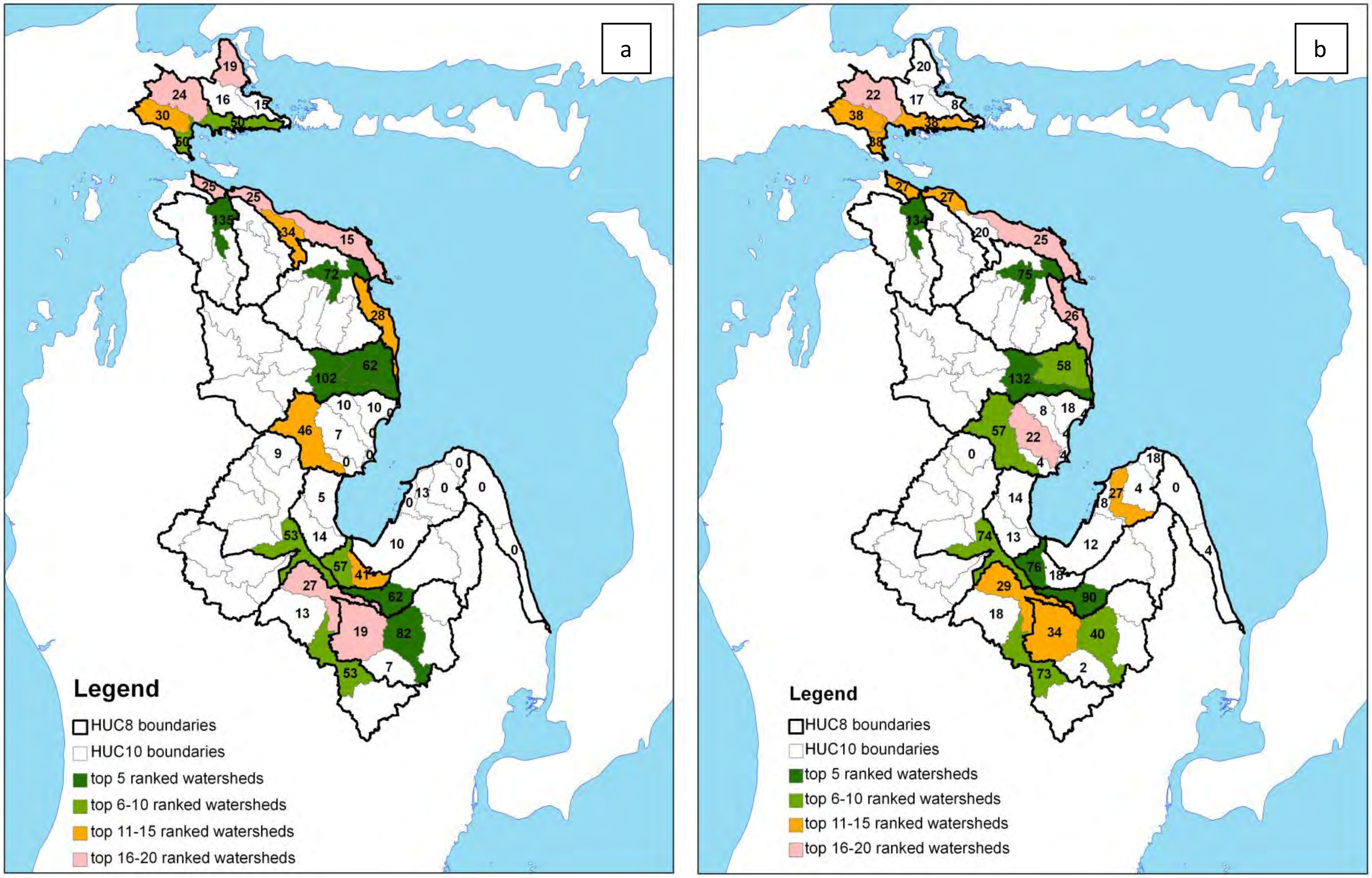


Figure 7a-b. Across species ranking of HUC10 watersheds based on the average index score for connected reaches within each watershed, grouped by highest scores. The number labeling each watershed is the sum of the ranks for each fish species across the watershed. Watersheds without numbers do not have connected reaches. Figure a shows the original calculations based on assembled data. Figure b has been revised to reflect expert review.

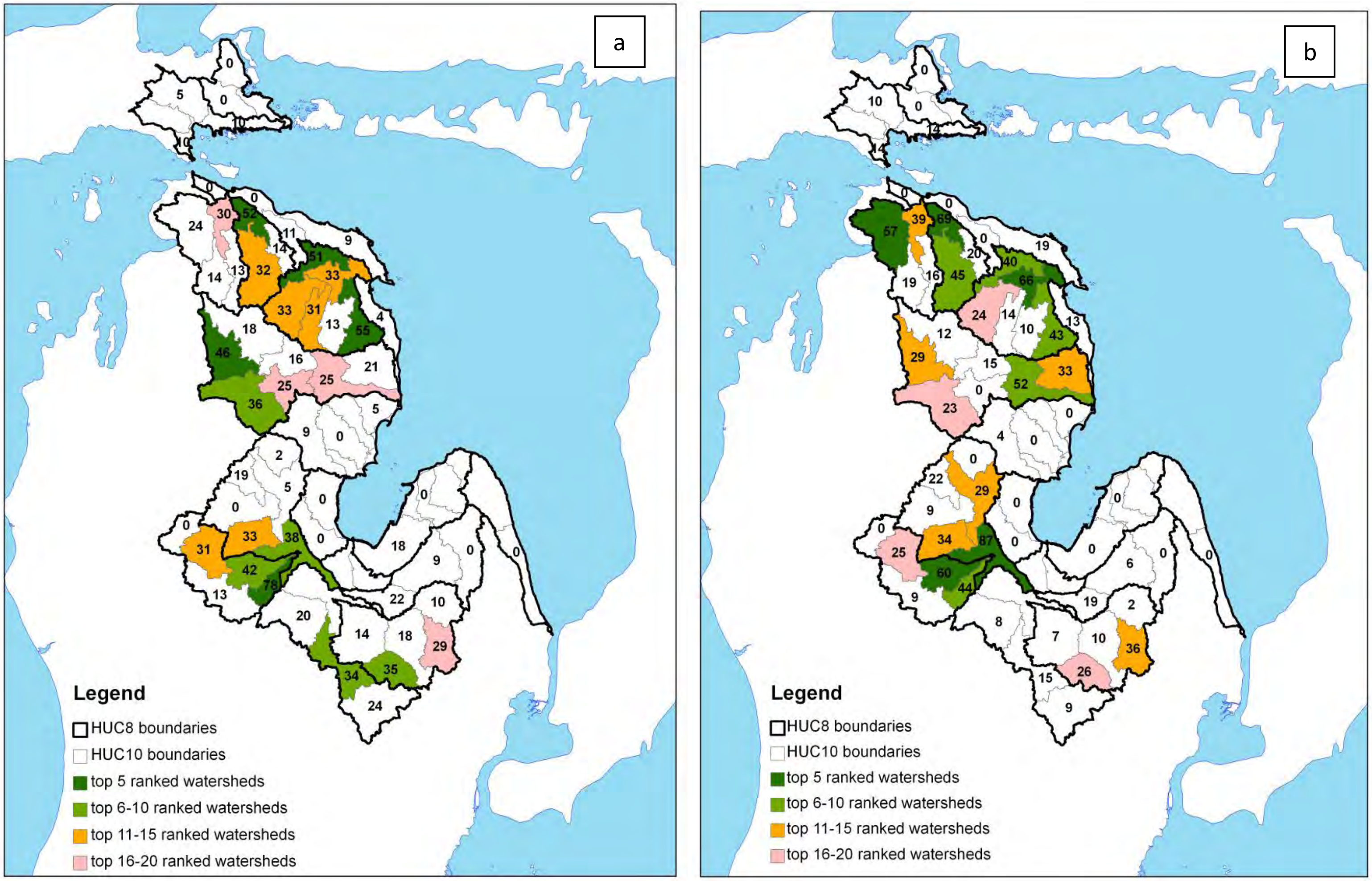


Figure 8a-b. Across species ranking of HUC10 watersheds based on the average index score for unconnected reaches within each watershed, grouped by highest scores. The number labeling each watershed is the sum of the ranks for each fish species across the watershed. Watersheds without numbers do not have unconnected reaches. Figure a. shows the original calculations based on assembled data. Figure b has been revised to reflect expert review.

8. Addressing data gaps and assumptions

There were three main questions raised during the course of peer review regarding the ability to draw conclusions about migratory priority based on the data we assembled. The first question was could we make use of abundance data that was not relativized (i.e. not corrected for sampling area)? Second, what was the effect of season on our analysis (in other words – was it a problem that some data were collected outside the spawning period)? Third, would sampling effort bias our identification of priority watersheds?

Abundance

For a subset of our stream data set, we had information on sampling area. We calculated relative abundance for those sites then compared those values to the abundance data to see how well correlated they were. The stream data set has 8652 records. Each record represents the occurrence of a species at a unique location and sampling date. Of those, 1193 records had both abundance and sampling area. We log transformed the data to create a linear relationship. Abundance and relative abundance were strongly correlated ($p < 0.0001$; $R^2 = 0.81$; Figure 9). We felt that this was strong enough to continue to use the abundance data for all 1956 samples that had abundance information.

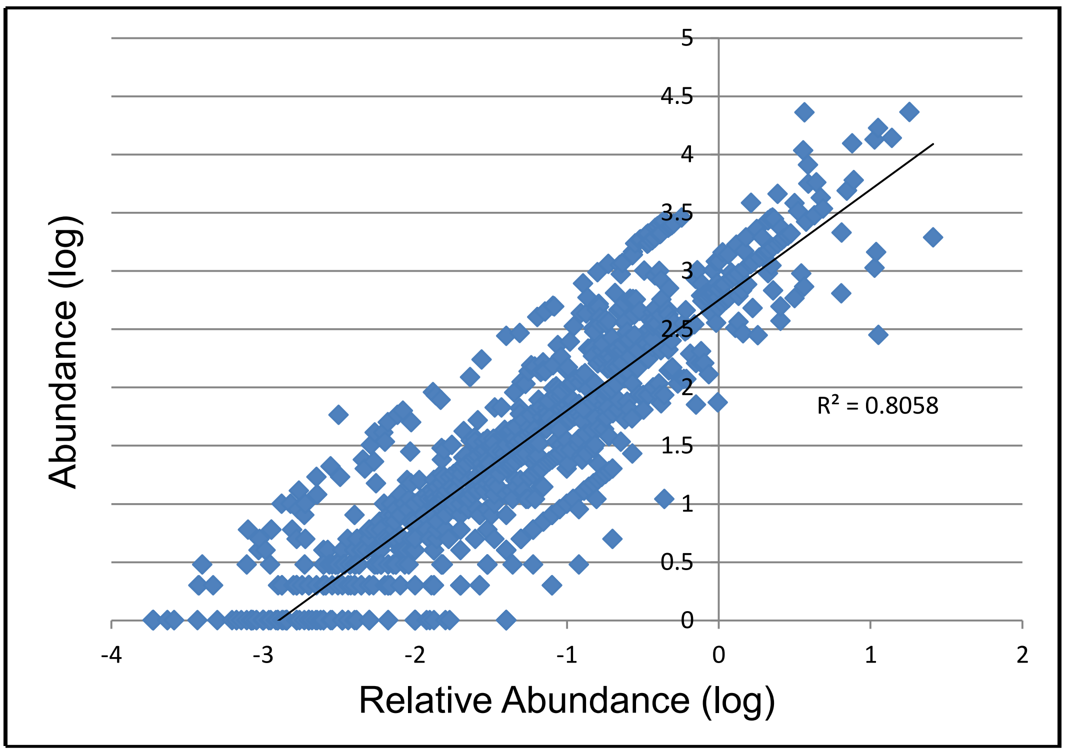


Figure 9. Scatter plot showing relative abundance (log) v. abundance (log).

Effect of season

It was our assumption that collection of a particular fish species during the spawning season would be stronger evidence of the importance of that habitat than collection outside of the spawning season. However, spawning season is variable among species and most of the collections fall outside of the spawning period for most species. Since spawning runs tend to result in high concentrations of fish within spawning reaches, we assumed that abundances for many of these species would be higher in collections during the spawning season. As a result, high concentrations of spawners would be reflected in the abundance metric of our index. To look at the effect of season on our data, we compared abundances of species in the spawning period to the non-spawning period. We had both abundance and sampling date for 1465 records. This represented 21 species. We determined the spawning period for these species from the Ontario Freshwater Fishes Life History Database *(The link provided was broken and has been removed)*, Trautman (1981), and Becker (1983).

We then calculated the mean abundance and standard deviation for the spawning period and non-spawning period (Table 8). For nine species, the mean abundance was higher in the spawning period than in the non-spawning period. For three species, the reverse was true. One species was collected only in its spawning period, while seven were collected only in the non-spawning period. Monthly abundance data for walleye (Figure 10) shows much higher abundances in March and April, which we believe likely reflects spawning concentrations. In general, we found higher abundances during the spawning period for most species where sampling occurred both within and outside of the spawning period – so those locations scored higher as anticipated. It is not particularly surprising that this was not the case for all species, given the general lack of surveys to specifically assess migratory fish populations.

Table 8. Abundances compared between spawning period and non-spawning period. Species for which we had no abundance information are not included in this table.

	spawning period			non-spawning period		
Species	**mean abun**	**StdDev**	**samples**	**mean abun**	**StdDev**	**samples**
Black redhorse	2.00	--	1	4.75	3.86	4
Brook trout	722.67	945.33	126	115.31	226.94	296
Burbot				5.18	7.12	11
Channel catfish	2.58	1.08	12	3.53	2.45	15
Channel darter	35.00	0.00	2			
Freshwater Drum	6.71	3.82	7	4.75	2.99	4
Lake sturgeon				4.00	--	1
Longnose gar	7.33	9.29	3	1.00	0.00	2
Longnose sucker				2.00	--	1
Northern Pike	3.30	3.32	37	2.25	2.41	115
Quillback	7.67	3.79	3	11.50	21.86	6
Round whitefish				17.00	30.18	6
Shorthead redhorse	8.33	8.08	3	6.23	7.74	13
Silver lamprey				3.00	--	1
Silver redhorse				3.91	4.97	11
Smallmouth bass	6.94	7.30	18	17.28	24.18	107
Spottail shiner	75.50	105.36	2	13.44	25.50	9
Walleye	164.06	596.49	31	27.91	65.55	34
White bass				4.00	1.00	3
White sucker	18.79	23.18	76	12.84	22.04	368
Yellow perch	571.52	1208.07	42	7.59	22.50	95
total samples			363			1102

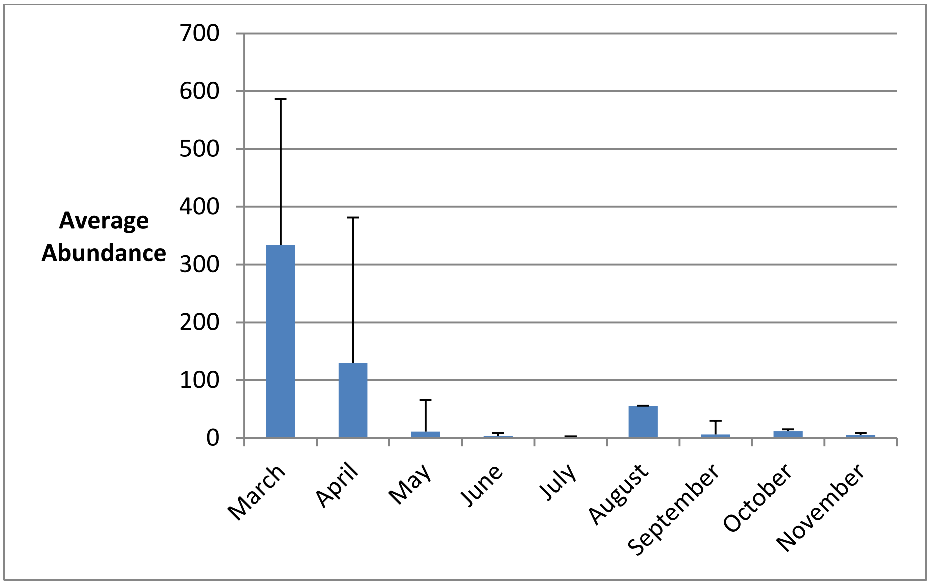
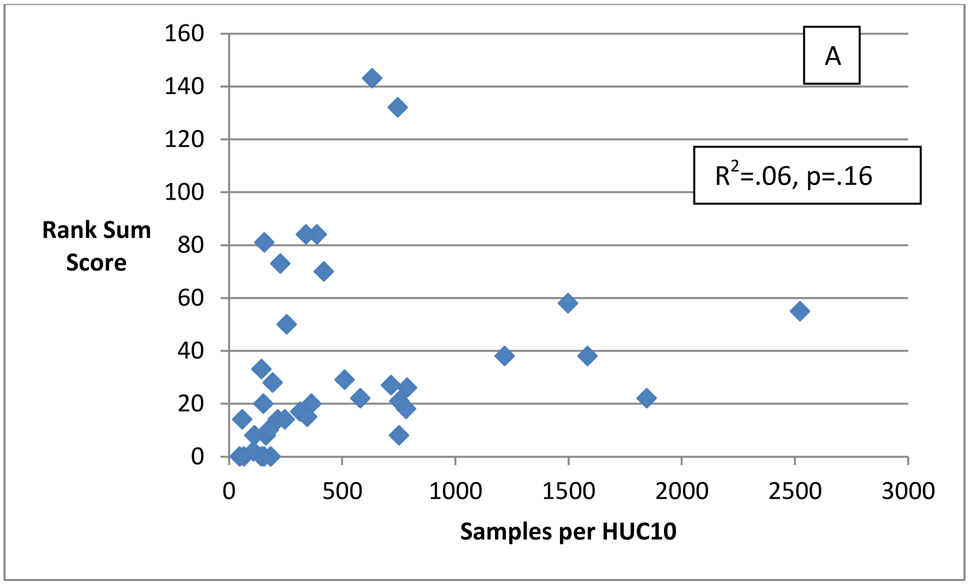


Figure 10. Average walleye abundance by month.

Effect of sampling effort

We recognized from the beginning that we would have data gaps due to uneven sampling effort and different objectives for sampling. We corrected for these biases in three ways. First, in the calculation of the species-reach index scores, we used an override rule so that we always used the higher of the maximum and the average rank for abundance. In that way, we gave greater weight to places that had high abundances. Second, we averaged index scores across HUC10 units to identify priorities for species and across all species, rather than identify priority stream reaches. Finally, we compared watersheds across all species by adding watershed rankings for each species, rather than index scores.

One test to see if we were successful in correcting for uneven sampling effort is to compare the final sum of all the species ranks for each HUC10 watersheds (rank sum) to the number of samples in that HUC10 watershed. We made scatter plots for the rank sum based on connected and unconnected reaches against sampling effort. For both connected (Figure 11a) and unconnected (Figure 11b) reaches there was no correlation. This lack of relationship indicates that uneven sampling effort was not a significant factor in determining watershed priorities. However, migratory fish species richness does increase with sampling effort across HUC 10 watersheds ($p = 0.014$), driven by lower richness for watersheds with sampling effort <165 collections (Figure 12). Without these watersheds, there is no relationship between sampling effort and species richness ($p = 0.21$). Since species richness is correlated with our index scores for connected ($p < 0.0001$) and unconnected ($p < 0.001$) watersheds, there may be some influence of sampling effort in the priority watersheds selected. Therefore, some watersheds with fewer than 165 collections (see Figure 13) may be of higher priority for migratory fish than our analyses suggest.



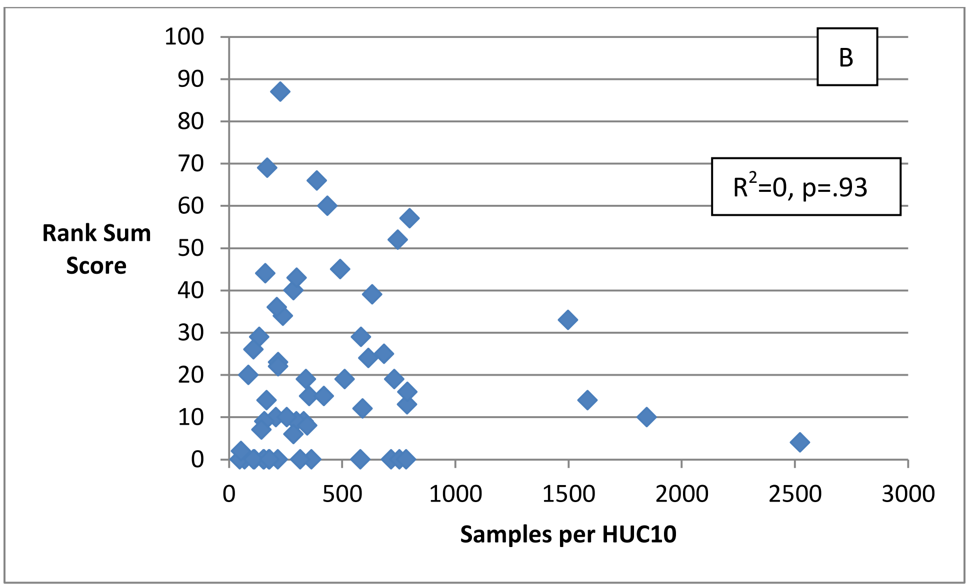


Figure 11a-b. Scatter plot showing relationship between sampling effort and the rank sum score used to prioritize among HUC10 watersheds across all species for the connected reaches (a) and unconnected reaches (b). In neither case is the relationship significant.

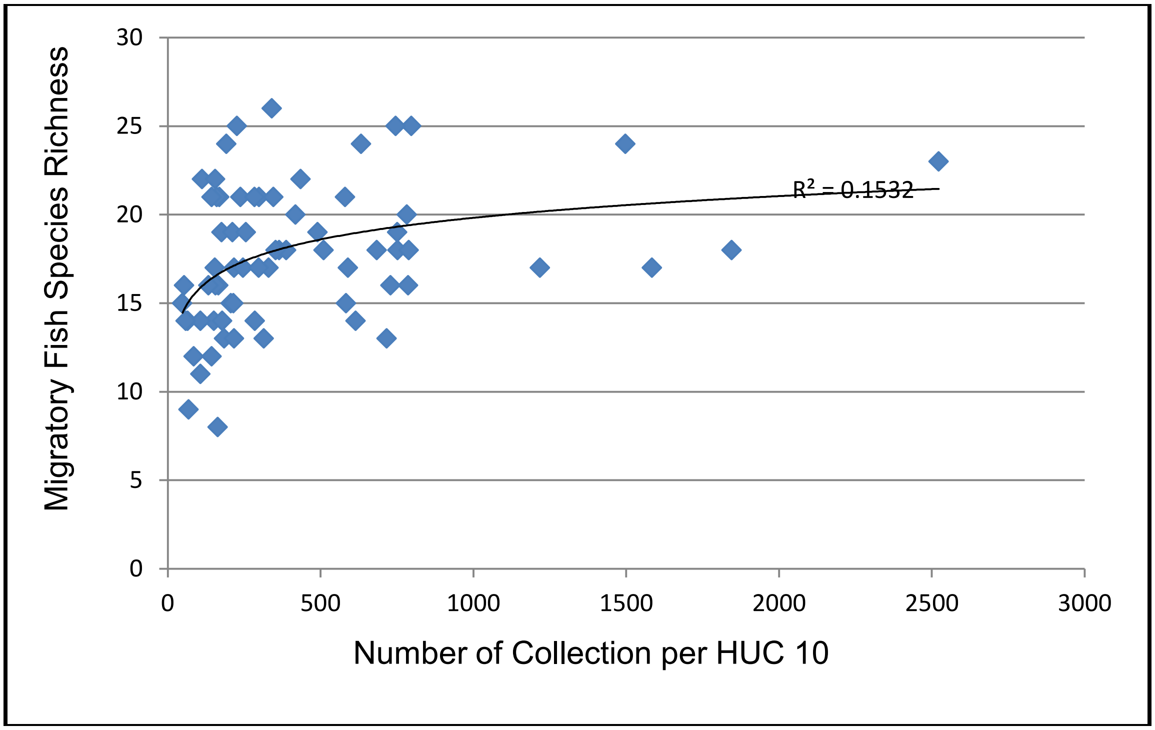


Figure 12. Relationship between sampling effort and migratory fish species richness across HUC 10 watersheds.

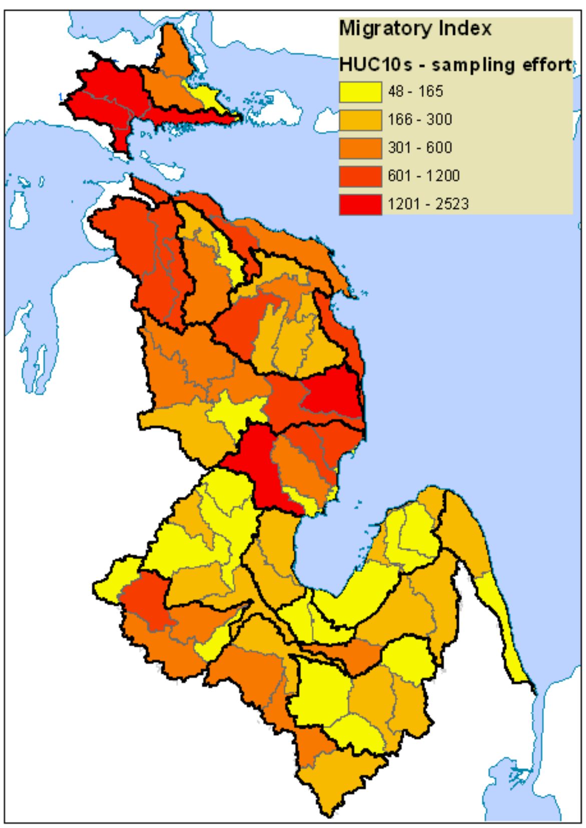


Figure 13. Sampling effort across HUC 10 watersheds.

9. Knowledge, data and information gaps

Throughout the development and literature review stages of the project, we compiled a list of data, knowledge, and information gaps. The list was sent out to regional experts for review and was the focus of a workshop held in Bay City, MI. The list was modified based on input during the meeting and at the end of the discussion votes from each participant were tallied to develop a list of very high and high priorities. Since the information gaps listed generally represented broader priorities that are called for in many Great Lakes conservation plans and since development of these information resources would be easier and of higher quality if key data and knowledge gaps were addressed, discussion and prioritization was focused on data and knowledge gaps. Workshop participants agreed that each of the information gaps were of high priority. The final list of gaps is shown in Table 9.

In general, experts agreed that gaps in knowledge, data, and information related to Great Lakes migratory fish were vast. Gaps ranged from questions specific to fish life history or population status to questions related to differential influences of barriers. Very high priorities to address included 1) increasing knowledge about which species have populations that migrate into tributaries, 2) the functional services migratory fish provide, and 3) identification of dams that are barriers and to which species. Some gaps were not considered a priority, such as species specific studies, because experts felt they were not feasible given the extent of the gaps and limited resources. Others, such as the size and importance of historic runs, were considered impractical given lack of historic information. For full proceedings of the knowledge, data, and information gaps workshop, please see Appendix 1.

Table 9. Key knowledge, data, and information gaps for Great Lakes tributary migratory species.

Knowledge

- **Which species have populations that move from the Great Lakes to the tributaries and to what degree?
- What are species-specific migratory distances?
- How important were historic spawning runs for each species overall and for distinct populations?
- How large were historic runs?
- *What is the spawning habitat for each species (general, as well as specific habitat that would allow for accuracy in modeling spawning habitat)?
- What threats impact spawning habitat?
- *How much habitat is needed to sustain populations?
- How large were historic populations of migratory species in GL (e.g., sauger, mooneye in Lake Huron)?
- *What migratory runs current (and historical) represent(ed) ecologically significant units?
- **What functional role/service do migratory fish runs provide for tributaries and Great Lakes?
- What is the cultural value of particular species?
- How significant is contaminant transport by migratory fish an issue, and where is it an issue?

Data

- Are there adequate species specific studies?
- *Is there adequate seasonal sampling?
- *Is there spatially explicit habitat data to predict spawning?

Information

- +What are the priority tributaries and barriers for Great lakes migratory fish?
- +**Which dams are barriers and to which species?
- +What is the relative likelihood of removing, repairing, or redesigning a particular barrier?
- +Which dams are critical barriers to key invasive species habitat?
- +Where are the most significant areas with problem road-stream crossings for migratory fish passage?

**considered very high priority by workshop participants
*considered high priority by workshop participants
+all information gaps were considered high priority, but these gaps were so comprehensive we focused prioritization on knowledge and data gaps.

10. Discussion

Our results represent the first attempt to comprehensively map the importance of tributaries to Great Lakes migratory river-spawning fishes across a broad geography (Western Lake Huron). Despite gaps in knowledge of the ecology of many of these species and a paucity of data collected specifically for the purposes of evaluating migratory fish populations, we believe that the results of this effort were successful in identifying the relative importance of tributaries to native migratory fish. We successfully combined a large amount of collection data that was widely distributed across the project area, including integration of collections in Lake Huron itself into nearby stream reaches. Most of the data were actual collections and were weighted for frequency of collection and higher abundance. The analysis approach was evaluated and improved upon through review with several regional experts early in the process. Regional fish biologists familiar with these systems reviewed the output and recommended limited adjustments to the output for most species. We then revised our across species analysis to reflect their adjustments and the resulting changes did not fundamentally change the priority watersheds maps. Therefore, the priority tributary maps provided here can and should be used (in concert with other data layers such as feasibility and risk) to help drive conservation decisions across the project area. However, there are substantial gaps in knowledge, data, and information on Great Lakes migratory river-spawning fishes and addressing these could certainly improve efforts like this.

Across all species, highest priority connected watersheds were the lowest reaches of the major rivers, the Cheboygan, Au Sable, Thunder Bay, and Saginaw/Tittabawwassee/Cass. This was generally the case both before and after expert input, though the importance of these systems increased after integrating expert input. Other important connected tributaries include the lower Shiawassee, the Pine Branch of the Au Sable, the Rifle, and the North Branch of the Flint River. Streams along Michigan's "thumb", which are mostly connected, had no priority connected watersheds prior to expert input, but the Pigeon River watershed did become a priority (top 15 watershed) following expert-driven adjustments. UP tributaries, which are also mostly connected, contained three priority watersheds. It is notable that the tributaries in the Shiawassee Flats area, where five tributaries converge upstream from the Saginaw River, appears to be an important area for many Lake Huron migratory fish. In general, tributary priorities changed relatively little after modifications made based on expert review, though important adjustments were made.

For unconnected watersheds, the priorities across all species were the Tittabawassee watershed, the Cheboygan watershed, the lower Thunder Bay and the lower Au Sable. Expert input resulted in relatively minor shift that primarily resulted in shifts away from the upper portions of the Au Sable and Thunder Bay Rivers. The importance of these areas for migratory fish should be weighed against other factors (e.g., invasive species distributions, feasibility) to develop priorities for dam removal or fish passage projects.

While this effort was generally successful, there are issues that need to be acknowledged. For one, using fish collections to identify important spawning areas above dams is obviously problematic since Lake Huron migratory fish no longer have access to those areas. However, several aspects of our analyses help to minimize this as an issue. First, the use of the Aquatic Gap predictions provided data on predicted habitat above dams, since these models generally did not factor in connectivity for most species (Steen 2008). In addition, many of our datasets included data that was quite old. For example, the Michigan Fish Atlas includes collection data dating back to 1823. Most importantly, in developing priorities, we developed two sets (connected and unconnected) so that we were not comparing tributaries above dams with those below dams.

There are other issues as well. Our abundance data was not relativized, but as we demonstrated in our analyses the unrelativized abundance data corresponds well with the relativized abundance data, so we are confident that the abundance data does generally differentiate between habitat of high, moderate and low importance. While less conclusive, we found that sampling season was reflected in mean abundances for several species. Finally, we concluded that our efforts to dampen out the effect of uneven sampling effort were successful as there was no relationship between the final score of watershed across all migratory species and the number of samples in those watersheds. However, we did see an impact of sampling effort on species richness, which suggests that there is a bias that needs to be corrected through better distributed sampling efforts in the future. In particular, we recommend that those waterheds with lower sampling effort (<165 collections across the datasets used here) be the focus of more intensive sampling.

Given the existing knowledge and data gaps on migratory fish, we felt this was the best approach for identification of important migratory fish tributaries. There are other options that we considered that could be explored in the future. Perhaps the ideal approach would be a Gap type predictive approach. But that approach would require a dataset specific to migratory fish, which does not currently exist in our study area. Another effort could be undertaken to map spawning habitat for each species. However, for many of these species the spawning habitat is only generally known. Further, data for many habitat features are not available at a sufficient scale to be useful (Hayes et al. 2009). It is our opinion that our approach is likely the best available approach given existing gaps in knowledge and data. However, a habitat mapping approach based on best available information and data could provide information complementary to our results.

The limitations described above are largely a reflection of the data, knowledge, and information gaps that exist for Great Lakes migratory fish. In order to fully understand fish movement patterns, you need data at high resolution over large spatial and temporal scales (Fausch et al. 2002). Unfortunately, most stream fish data collected in this region fall within a narrow window during summer, and do not adequately cover the spawning period for most species. More seasonally dynamic monitoring schedules would help to alleviate this. More species-specific information related to migratory fish populations—even from research or monitoring on whole fish assemblages—would vastly improve our knowledge of Great Lakes migratory fishes and their use of tributary habitat. A recent comprehensive review of fish movement studies in the Great Lakes found that only 11 of the species evaluated here have had movement studies conducted on them, and for five of those species there were three or fewer studies (Landsman et al. 2011). Experts consulted during this review generally believed that these migratory species were generally not limited by migratory distance up tributaries, since Great Lakes river distances are relatively small in comparison with distances many of these fish migrate within the Mississippi or Ohio River systems, and therefore our analysis did not include a filter for distance to Lake Huron. However, in species specific conversations, it is clear that some species do tend to migrate in much greater numbers closer to the Great Lakes (e.g., brook trout, yellow perch, northern pike). In addition, Jones et al. (2003) demonstrated that there are biological limitations with how far upstream walleye can successfully spawn and survive. More research on these distances and which species are limited by them would improve future analyses like this.

When combined with other information, the comprehensive, multi-species priority tributaries for migratory fish identified here can play a key role in making better decision on where to conduct tributary conservation efforts, and how much is needed. In order to be effective, these results would need to be combined with other data to make quality decisions on resource expenditures. For example, connectivity restoration decisions should also consider locations and types of dams and other barriers, current condition of habitat, feasibility and opportunities for barrier removal, and current and potential distributions of invasive species such as sea lamprey and round goby. In addition, the individual species maps would also play an important role in decision making. The types of individual species should help to determine key conservation decisions, such as whether fish passage around a barrier is sufficient or whether dam removal would be required to provide access or restore habitat. This information could play an important role in an integrative approach to barrier management, as was called for in the Lake Huron Biodiversity Conservation Strategy (Franks-Taylor 2010).

The approach taken in this study provides critical information on native migratory river-spawning fish that will result in making better decisions in protecting and restoring Lake Huron tributaries. We believe that this effort—or a similar effort—should be expanded into other portions of the Great Lakes.

Finally, we have identified many gaps in knowledge and data on Great Lakes migratory fish. It is critical that Great Lakes researchers and fisheries managers begin to address these gaps. Many of these gaps are vast, and will require significant investment of time or resources. To be most effective, these efforts should be well coordinated to ensure that investments are maximizing the information that results.

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Development of Conservation Priorities for Migratory,

River-spawning Fishes in Lake Huron

Appendix 1

Migratory Fish Data and Knowledge Gaps: Proceeding of an expert's workshop on Great Lakes migratory fish, Bay City, Michigan, 4 August 2011

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Background

The following is a summary of a meeting held August 4th, 2011 to bring together experts to discuss knowledge, data, and information gaps with regard to Great Lake migratory river-spawning fishes. Prior to the meeting, we spent months gathering information and data to map Lake Huron migratory fish populations, including developing a list of native migratory species, identification and acquisition of data relevant to migratory fish, data preparation, and analyses. During each phase of the process, we kept a list of knowledge, data, and information gaps. In preparation for this workshop, we organized this list, and supplemented it with additional gaps following further literature review.

We classified gaps into knowledge, data, and information to foster a better understanding of the work that would be necessary to address them. For this purpose, knowledge refers to fundamental gaps in what we know about migratory fish or how they interact with their environment. For example, when we were developing our initial list of species, we encountered a lack of knowledge about the life histories of several fish species, specifically whether they are truly Great Lakes migratory river-spawning fish. Data gaps occur when the data collected is insufficient to build knowledge (such as which species are migratory) or to address critical information needs. For example, we took advantage of many fish collection datasets in mapping Lake Huron migratory fish, but there is no specific effort across the study area to collect data to evaluate migratory fish populations. Finally, information refers to products strategically developed through the use of knowledge and data that can be used to broadly answer ecological questions and to make key conservation decisions.

The workshop discussions focused primarily on data and knowledge gaps since the information gaps are broader resources that are generally called for in many Great Lakes plans. Development of these information resources would be easier and of higher quality if key data and knowledge gaps were addressed.

Meeting Agenda
Addressing Migratory Fish Data and Knowledge Gaps

Thursday, August 4, 2011 10:00am – 4:00 pm
Delta College Planetarium & Learning Center
http://www.delta.edu/files/Maps/Bay%20City%20Map-7-09.pdf
100 Center Ave.
Bay City, MI 48708
(989) 667-2260

10:00 – 11:00	Introductions Overview of day Overview of migratory fish mapping project Review of data and knowledge gaps identified so far
11:00 – 12:00	Presentations by participants Michelle Selzer, DEQ Dave Fielder, DNR Jeff Schaeffer, USGS – Great Lakes Science Center Catherine Riseng, U of M Jessica Barber, USFWS – Lamprey Program Tracy Galarowicz, CMU Brent Murray, CMU Dan Hayes, MSU Patrick Ertel, Huron Pines Matt Diebel, WDNR Evan Childress, U of WI – Madison Dan Oele, U of WI – Madison Others pending
12:00 – 12:30	Lunch (provided)
12:30 – 1:30	(if needed) Presentations continued
1:30 – 3:30	Discussion of data and knowledge gaps
3:30 – 4:00	Prioritization of data and knowledge gaps

Workshop Attendees

Expert	Affiliation	Participation
Andrea Aniea	US Fish and Wildlife Service	Present
Anjie Bowen	US Fish and Wildlife Service	Met with before meeting
Brent Murray	Central Michigan University	Present
Catherine Riseng	University of Michigan	On phone
Dan Hayes	Michigan State University	Present
Dan Oele	University of Wisconsin	On phone
Dave Fielder	Michigan Department of Natural Resources	Present
Ed Rutherford	National Oceanic and Atmospheric Administration	Met with before meeting
Evan Childress	University of Wisconsin	On phone
Gary Whalen	Michigan Department of Natural Resources	Met with before meeting
Jacob Stoller	Michigan State University	Present
Jeff Schaeffer	US Geological Survey	Present
Jessica Barber	US Fish and Wildlife Service	Present
Kyle Kruger	Michigan Department of Natural Resources	Present
Matt Diebel	Wisconsin Department of Natural Resources	On phone
Michelle Selzer	Michigan Department of Environmental Quality	Present
Patrick Ertel	Huron Pines	Present
Paul Seelbach	US Geological Survey	Met with before meeting
Stephanie Januchowski-Hartley	University of Wisconsin	On phone
Tracy Galarowicz	Central Michigan University	Present

General Discussion

- Consider **suitable habitat upstream** of obstructions: not only macrohabitat (flow regimes, substrate, grade) but also more specific needs of species in microhabitats.
- Remembering **habitats are not static**, especially with removal of dams. Assess at geographic scale, but consider the temporal nature of habitat conditions. Different requirements for different species.
    a. Watershed changes, development, deforestation has changed habitat from historic conditions, as well as stream obstructions, climate change, etc…affecting future project management as habitats change, especially relative to spawning seasons.
- More important than issue of migration is **effective recruitment**.

Data and Knowledge Gaps Discussion

Knowledge Gaps

Migratory Behavior – Which species have populations that move from the Great Lakes to the tributaries and to what degree? (Question 1)

- Qualitative expert opinion exists, but with significant uncertainty for many species. Some we know, others based on anecdotal information.
- Consider a **gradient in migratory fish from facultative to obligate**. Suckers can live and spawn in lakes and are not obligatory migrators, they are facultative. Some are obligate migratory species (redhorse sp) and can't just live in lake or stream – they need to move. Not just "if" they migrate, but the degree to which it is necessary in their life history.
- Rating **importance of Lake Huron** to each fish species. Low – High.
- **Phenology**: Rather than asking about migration for spawning, ask about migration for some time in their lifecycle. Be it temperature related, phenology, etc… They may come and go depending on environmental conditions, rather than just spawning drive.
- **Expert Opinion** - This may be a topic that biologists have a qualitative idea about.
- Workshop participants considered this a **very high priority** to address.

Migratory Distance – What are species-specific migratory distances? (Question 2)

- For most species, it is unclear whether and how much distance limits their migration upstream. Migratory distance data exists for some species.
- **Size of rivers**: Rivers in GL basin are fairly small. Distance within these systems may not apply to all populations of a species.
- Walleye in Maumee – study showed max distance due to larvae death due to **metabolic constraints** before they reach the lakes.
- **Quality of habitat** can drive migration distance, where is the good habitat? That's how far they go.
- Pike in NY – **natal homing**; **genetically**, if they're imprinting to a specific spot, this affects distance. Amount of stray affecting this if there is strong natal homing. Migration distance may be constrained by homing.
    - Muskellunge go from bay to bay spawning sequentially. Pike are spot specific year after year based on jaw tags.
- The **capacity** to move long distances is in their biology, but knowing a sturgeon can go 200 miles doesn't make it a functional distance. **Dams** will make physical ability a mute point. *Most fish can make it to the first dam in rivers of the GL Basin.*
    - Northern Pike in Green Bay – anecdotally, fewer records of YOY from tributary locations further inland. This may be distance limiting rather than barrier limiting.
- Workshop participants considered this a **moderate priority** to address.

<u>How important were historic spawning runs</u> for each species overall and for distinct populations? How large were runs? (Questions 3 and 4)

- **Specialists and Generalists**: Some species are very flexible; they are generalists for spawning habitat, size is less important because more of the available habitat is considered suitable. For species with very specific spawning requirements, more accessible area is necessary to account for these specific habitat requirements.
- **Limited historical accounts**: There could be even more history before our anecdotal accounts begin. Even more fish may have migrated than historical accounts indicate. We may never know.
- What difference does it make? Habitats are different; different applications. Doesn't help to set goals because "historical conditions" are unattainable. **What we should focus on is what we can attain and what is necessary to sustain populations.**
    - What can we do relative to current conditions, rather than historic conditions? That's the change we need to look at, and relative to cost/barrier removal. And, is it enough? This helps us decide where to take out barriers.
    - Historic run size estimation gives **insights into science but not management**.
    - White fish in Manistique – historic content can give us insight into what is realistic.
    - All the introduced species have changed the conversation. Ag fields applying so much more nutrients, we can't take that away completely. It's not oligotrophic like it used to be, even if we shut off the farms, it's changed forever.
    - How important were runs for stocks of fish? Maintaining stocks is what we should be focused on.
- It's about the **functional role in the ecosystem**. What are these runs contributing to the functionality of the systems.
- What can we do to reach a certain **level of productivity**?... to maintain stocks and functional ecosystem services? One could move the bar/goal to get the funding we need to do it.
    - We don't know what these spawning runs contribute to lake stock levels. We don't know how much that affects stock.
    - If we were able to provide more migratory/spawning habitat in the rivers, would we see more in the lake? If we took rivers out of the picture we would have no sturgeon, white sucker might be impacted, lake trout or white fish may not be that much affected.
- What is the **limiting factor for each species**? Is it necessarily spawning habitat or something else? We have to identify what our assumptions are.
- Workshop participants considered these **moderate priorities** to address.

What is the spawning habitat for each species (general, as well as specific habitat that would allow for accuracy in modeling spawning habitat)? (Question 5)

- Qualitative expert opinion is generally available for most species, but knowledge/data/information sufficient for predictive models is needed.

- Don't have the models to predict where a species would spawn. Qualitatively, biologists know what many species need and where they spawn. Managers need to know to what extent species will use restored habitat when looking at removing barriers and gaining funding.
- We need to have **assurances** that certain species will benefit from opening up a barrier.
  - **Funding sources** are available from organizations geared to benefit **specific species**.
  - What do you restore **relative to the costs**? If you remove particular barriers what are you going to get?
- In a proposed dam removal you want to look at **all the species that could benefit** from that. The models are not there to show unequivocally what species would need or use. Qualitatively, biologists can pretty much tell what a species needs, where it spawns. But, we don't have the data inputs on a fine enough scale to make the models give us a realistic output.
- Workshop participants considered this a **high priority** to address.

What <u>threats</u> impact spawning habitat quality? (Questions 6)

- Literature exists for most of this but there are additional considerations. However, they are typically only generally known. To better understand this, the gaps in our understanding of detailed spawning habitat (#5 above) will need to be better understood.
- What **processes** affect instream habitat? Lots of unknowns. We can measure temperature, but not all the factors that contribute to this.
  - Even if the flow and substrate are right, you still have anthropogenic influences (Impervious surfaces, runoff, etc..) that compromise a habitat. Qualitatively, we understand it, but we don't have the details of species requirements. See above question comments.
  - It's partly a **water quality** issue. Can we have conditions that are okay for spawning but not survival of offspring? There are **traps**. There are times we don't have to know why the water quality is bad but we know instinctively that it is.
- This may not be a knowledge gap. Stream literature has thousands of studies relating water quality to watershed characteristics. **The knowledge is out there, it's just a matter of searching, reading, and synthesizing.**
- Workshop participants considered this a **moderate priority** to address.

<u>How much habitat</u> is needed to sustain a population? (Question 7)

- This is an impediment for decision making. Need data and information on how much spawning habitat we need.
- Must also remember to ask whether the river habitat is the limiting factor. There may be available spawning habitat that is underutilized because of factors going on in the lake.
- It will vary with the species and the quality of the available habitat.
- Two streams could be different because of **history and legacy effects**, one is good and one is poor quality. As a scientist we want to know why. As a manager, if you know what's wrong you

go ahead and fix it. People don't need to understand why they have a headache; they take an aspirin and don't worry about the biochemistry. Are we looking for a cure or remediation?

- Workshop participants considered this a **high priority** to address.

How large were historic populations of Migratory Species in GL? (Question 8)

- Given historic accounts of historic spawning runs, we know that tributary spawning migrations from the Great Lakes were vastly reduced from historic conditions. Many contend that those reductions were probably much greater than we realize, since the historic accounts are just a small snapshot.
- We don't really know and probably can't completely fill this gap.
- **Weighting of species**. Why do we weight species? In PCAs we always take multivariate axes and make them univariate when we try to interpret. We want to score on rarity, but there's different kinds of rarity. A weighting scheme muddies the information. There's a communication aid to having one map of all species. But when we do things, we do them from species to species, it's how we think about things.
- The more important question is **how populations relate to the ecological function**. We have a perception that sturgeon were very important to ecosystems historically, but now we don't have them.
- Let's focus on sturgeon, they're a **flagship species** with no debate. Any fish passage program or approach that works for sturgeon is probably going to work for any other species. They could be the linchpin species. If we program for them, everyone else gets a free ride.
    - Funding driven by stakeholders that probably won't recognize fish they don't eat. Different species are important to different people and you need support from all of them. Also, people need to be motivated to see benefits, especially if they're going to lose a spot to boat or jet ski.
    - You have to appeal to the funding source and use an **umbrella species** that targets that funding source and also a specific habitat. But the same project can benefit multiple species that can be supported by many funding sources. You can talk about different species benefits to different people even about the same project.
    - Some people are not fans of umbrella species because everything is context specific.
- The reason we have these data gaps is because we've included species we think are migratory. But, we don' t know anything about their life histories. What if we **focused on species we know more about**. Rather than taking a biodiversity approach, we've tried to include all these other species where the information about their life history isn't out there, isn't familiar.
- Restoring the ***potential*** for fish to migrate. We can say we're opening habitat for sturgeon, but sturgeon might not go through, although tons of other fish might. But then how do we measure our success? **Measure success on potential production, ecological function rather than specific species.**
- Workshop participants considered this a **moderate priority** to address.

What migratory runs current (and historically) represent(-ed) ecologically significant units? (Question 9)

- This knowledge would have a variety of implications. Current ESUs should be of higher priority for conservation. Historic ESUs would be of high priority as well, but they might also mean that restoration of a run is less feasible if the ESU is gone. Lots to work out, but definitely important implications.
- Evolutionarily distinct units. Some data on game fish, very little on non-game fish. Must consider the habitat available and that there is enough habitat spread across an area to afford a buffer against disasters and to offer increased gene diversity. Must also account for stocking in numbers and ecological roles.
- A **percentage of potential:** If 99% of species population is spawning in one place, they're very susceptible to damage that happens in that place. We need to plan for protection from catastrophic events.
    - Tittabawassee seems to meet larval production needs of Saginaw Bay, but all the eggs are in one basket. Historically, Saginaw Bay benefited from multiple spawning runs/ecologically significant units. It's not just meeting a safe number of recruits, its spreading them over an area.
- Also, some **genetic differences** across contributing tributaries (Wilson). Not that much information out there on population genetic differentiation. See Pete McIntyre – Green Bay suckers genetics work.
    - You can find genetic differences between anything that can be used for different purposes.
    - The **homing** question relates to this. Every spawning location is probably distinct. But in some species homing is important, for another species it might not be. Better evaluation of the homing issue could inform where genetics are most important.
    - Look at distinguishing evolutionarily different eco units.
- Look at **stocking and hatcheries**, you have to account for stocking.
- **For 90% of fish species in N. America we don't have basic information**, cursory info. Non-game fish have little information available. Some data on game species. We just don't have that much. How many golden red horse papers do we have? Hardly any.
    - Knowing something about these topics for the future – if something happens and we lose these species … we don't always know what will be catastrophic. Are these dams part of that?
    - If we had knowledge of historic stocks we could have potential knowledge of what could happen, how they could come back.
    - We don't even know what the units are now, never mind historically.
- If you removed a barrier and had 10 **linear miles, v. more dendritic mileage** you'd have more protected areas. Different areas offer different amounts of protection, especially looking at more resilient or vulnerable species.
- Workshop participants considered this a **high priority** to address.

What <u>functional role/services</u> do migratory fish runs provide? (Question 10)

- There are many potential roles/services provided by each species.
- One ecological role is **nutrient supply**. *Huge knowledge gaps*.
  - It isn't just their historic ecological role. What is the role in *today's context*? The past function isn't necessarily what we need to know today.
  - Nutrient export from tributaries back to lakes. Larvae take nutrients from hatching habitat and carry into lakes. This isn't always considered, but could be an important role.
  - **Tributaries** and **nearshore** zones may be last sites of **traditional production**. Identified by EPA as a research program.
- **Interconnected species**: There may be some species whose abundance hinges on other species producing in a river.
  - There's something broken in Saginaw Bay. We don't really know what it is but one reason we may not have great perch survival is because there's nothing to buffer predation of walleyes on them. What's missing now? We used to have lots of perch. Alewives or ciscoe are gone. There was a linkage between the main basin, onshore spawning, and juveniles that used that as a nursery area. That was an important ecological buffer on perch. We needed something there to help protect them from predation. There's just a lot we may not know with these interactions.
- **Contaminants** that migratory fish could spread. Is that an issue? Look into papers on toxic transport by anadromous salmonids.
  - Body burdens in eagles feeding on fish in Au Sable. Walleye in Tittabawassee.
  - Do we really know the impacts of that? Before the bald eagle was delisted fish consumption was an issue. Contaminant transfer is an impediment to eagle recruitment and survival. Mink, Rick Westerhoff – ton of toxic transfer info, or E. Lansing FO Lisa William; MDEQ – ongoing sampling.
- There is a **social science** side. If there are communities that identify with a single species, they could they be solicited to target management.
  - Ex. If we introduced grayling in Grayling there would be festivals. Grayling used to be named Crawford, but they voted to change the name in honor of the fish. Black lake sturgeon spear fishing. Flushing in second year of walleye festival.
- Workshop participants considered this a **very high priority** to address.

<u>What is the cultural value of particular species?</u> (Question 11)

- What species resonate with local communities to help build support for restoration?
- Classic examples would include grayling to Grayling or suckers to Omer.
- By identifying, and potential further fostering, local cultural ties between specific migratory fishes and local communities, it can help identify opportunities for restoration.
- Workshop participants considered this a **moderate priority** to address.

How significant is contaminant transport by migratory fish an issue, and where is it an issue? (Question 12)

- Not clear how significant it is or how widespread it might be across the region.
- There has been discussion of this in the region related to bald eagles for some time. Recent research is suggesting that there definitely is significant transport in some areas, but the ecological significance still need further consideration.
- Workshop participants considered this a **moderate priority** to address.

Data Gaps

Are there adequate species specific studies? (Question 13)

- Most species would benefit from species specific studies to collect data on distribution, status, and migratory locations
- Typically good information for game species but sampling everywhere for everything is too costly. This may be an unfillable gap due to lack of resources.
- You want knowledge of all species in all places, but that's not going to happen. For any specific project you want to do a pre-evaluation. But you can't fill the gaps for everyone in every place.
    - Even though there are data available on catches, those data are almost uninterruptable, an absence of data is a non-detect, not an absence of fish. Catherine Smith – study on how much sampling do you need to represent a HUC10. **This may be an unfillable gap.**
    - The whole reason for **AqGAP** was initiated was because fish surveys are rare relative to stream reaches in MI. Lack of reach specific data.
    - Plus, it's all **temporal**, changes with the season. It costs money to find that information.
    - A lot of historical fish surveys are **targeted to game species**. Non-game species are often pooled in counts.
- Workshop participants considered this a **moderate priority** to address.

Is there adequate seasonal sampling? (Question 14)

- Most migratory fish species spawn in spring (some in fall). Most riverine assessments occur during summer, outside of the spawning period for most Great Lakes migratory fishes. Some migratory species may still show up in these surveys, but sampling across seasons would provide data much more effective at assessing migratory fish habitat.
- Existing studies are species and site specific. Requires large investment of hours sampling. Sampling time is not necessarily coordinated to spawning or migration of species being sampled.
- Walleye collection in Tittabawassee – but that's only targeting **walleye**.
- **Lamprey** distribution, status, spawning studied are known.
- You don't always know when the run is going to be. You have to sample frequently for all the sites you're interested in. There are always tradeoffs.

- Currently agencies have trouble meeting their current summer monitoring goals. It would be challenging to integrate additional sampling focused on spring sampling.
- Workshop participants considered this a **high priority** to address.

Is there spatially explicit habitat data to predict spawning? (Question 15)

- Currently, the resolution of most data layers does not provide enough detail to accurately predict spawning habitat for many species (e.g. type of riffle habitat).
- This data need is compounded by the fact that we don't adequately know the spawning habitat for many of these species (#5 above) and that there are no datasets specific enough to Great Lakes migratory fish (#14 above) for predictive modeling of spawning habitat.
- Any time you're improving the quality of a stream, **opening connectivity**, **there's improvement** that allows fish to be there and the stream continues to improve. Put back what stream function we can rather than looking at a specific species and take out dams that fit what we think they need. The fish that can use it will.
- In one instance a fish passage was put in to increase range, but it opened up a reservoir behind the dam, and a section of high flow stream right below the next dam, providing no spawning habitat. You have to **consider what is above** when looking at barrier removal.
- Workshop participants considered this a **high priority** to address.

Information Gaps

[Discussion on the following information gaps was fairly limited. Most of these represent broader priorities that are generally called for in many Great Lakes plans. Workshop participants seemed to agree that each of these is of high priority, especially which dams are barriers to which species. Since development of these information resources would be easier and of higher quality if key data and knowledge gaps were addressed, discussion was focused on those.]

What are the priority tributaries and barriers for Great lakes migratory fish? (Question 16)

- Should consider what would be conserved/restored, but also risks (e.g. invasive species), feasibility, and costs.

Which dams are barriers and to which species? (Question 17)

- The lowest barrier is different for lamprey, chinook salmon, and walleye. We have a limited understanding of barriers for most native species.

What is the relative likelihood of removing, repairing, or redesigning a particular barrier? (Question 18)

- When developing conservation priorities, we need to consider the conservation benefits and risks, but also the feasibility. A data layer that addresses the feasibility of removal for each barrier would be very helpful.

Which dams are critical barriers to key invasive species habitat? (Question 19)

- Increases in invasive species distribution and abundance are serious risks of barrier removal.
- Spatially-explicit information predicting habitat quality/spread of invasives following barrier removal, would be very helpful in developing barrier removal/retention objectives.

Where are the most significant areas with problem road-stream crossings for migratory fish passage? (Question 20)

- Given the vast number of potential problem barriers in the region, it is critical that efforts to assess and prioritize them are coordinated through quality data collection and management.

Participant Project Descriptions:

At the beginning of the workshop, participants were given the opportunity to provide a brief presentation describing work they were doing or had done on Great Lakes migratory fish. These ranged from power point presentations to brief descriptions of projects or expertise. These are briefly summarized here.

Mary Khoury/TNC – Mary gave an overview of the workshop objectives and a presentation on the larger project, including an overview of the effort to map Lake Huron migratory fishes to give context for why we are discussing knowledge, data and information gaps for Great Lakes migratory fish. The presentation covered the rationale for the project, the data sources, the methods used to combine the data sources, and preliminary results. Workshop participants suggested that the project consider suitability of habitat upstream of obstructions. For example, there may have been historic habitat above a dam, but the habitat may now be degraded. Along those same lines, it was pointed out that habitats are not static, especially with removal of dams. We should consider the temporally dynamic nature of habitat, not just spatial differences. There was an important comment regarding our use of abundance data used in the analyses, and the fact that it was raw abundance and not relative abundance. Given that multiple data sources were used, the raw abundance data may not reflect relative abundance at all since sampling effort could be quite different across the data. [This last question prompted us to conduct an additional analysis to evaluate the relationship between raw abundance and relative abundance, for those locations where we also had relative abundance.]

Michelle Selzer/DEQ-OGL- Stressed the importance of water quality in the tributaries and how this might impact decisions regarding Great Lakes migratory fish. For example, behind some dams there is a substantial load of toxins (e.g., PCBs, dioxins, mercury) in the sediments, so this is an important factor in considering barrier removal. In addition, a lot of historically important reaches may now be "lost causes" because of contamination or other water quality issues. Water quality information is available for tributaries of Saginaw Bay and could be used to evaluate against migratory fish priories. Review integrated report for pollutant problems as well as important species in reaches. Michelle sits on the Lake Huron Binational Partnership and she pointed out that this was probably the first project that emerged from the Lake Huron Biodiversity Conservation Strategy that was moving forward. Look to the Lake Huron Binational program, surface water assessment biologists who can help facilitate conversation w/DEQ scientists.

Dave Fielder/MDNR– Talked about numerous efforts that he is involved with that relate to Great Lakes migratory fish populations. For example, many of the surveys that the do in Lake Huron (spring lake trout survey, fall Saginaw Bay survey, St. Mary's River surveys, Thunder Bay surveys) would provide information useful in evaluating the status of migratory fishes. In addition they have been working on a jaw tagging program for walleye in the Tittabawassee River and have found substantial movement in this fish. In addition, they are implanting transmitters into walleye in Saginaw Bay, Thunder Bay, and the Huron-Erie corridor to learn more about the migratory behavior of walleye. He has been involved in an St. Mary's River surveys to evaluate status of fish populations—many migratory species—mostly during the summer (missing a lot of spring and fall migrations). Dave also pointed out that DNR-Fisheries Division has undertaken fairly exhaustive effort to review the historic and present conditions of many of the major tributaries of the lake, including evaluation of significant barriers to fish and priorities for dam removal. These should be reviewed when evaluating the migratory status of fish in Michigan. Dam removal as upcoming issue in MI.

Jeff Schaeffer/USGS-Great Lakes Science Center – Jeff's work is becoming more focuses on Great Lake-tributary connectivity linkages. Jeff is involved in the Great Lakes River mouth Collaboratory (https://www.glc.org/work/great-lakes-rivermouth-collab), which is working to better understand the ecological role of river mouths in the Great Lakes as habitat, nursery areas, production areas for invertebrate prey, etc. Focused on Ford, Pere Marquette and Manitowoc River (LMI) – pristine river, somewhat impacted, and heavily impacted for comparison. Looking at nutrient load, relating water chemistry to watershed characteristics, flow models, dynamic mixing zone, material deposition processes, and build ups. Jeff has been sampling larval fish every two weeks at the river mouth study sites, and will be analyzing chemical composition (e.g. fatty acids) to determine the relative contributions of riverine or lake processes within the river mouth zone. This work will improve our understanding of migratory fish. Jeff stressed that in prioritizing dams for removal, we should consider the habitat available to young fish as they enter the lake, and how this may have been modified from historic conditions. In removing dams, consider the young fish entering the lakes and the habitat that is no longer historic, pristine, complex, but highly modified. Focused on linkage between rivers and lake and needs of fish.

Jessica Barber/USFWS Sea lamprey Control – The sea lamprey program has had crews ground-truthing barriers over the last 4-5 years, focused on distance from the river mouth to the first blocking structure. These assessments include GPS, photos, and visual assessment of dams. Minimum standards for dams as barriers for sea lamprey include 18" vertical drop between cresting level and dam height. Assessments include looking for larval/spawning habitat for sea lamprey. This year, they will be looking at embankments, gates, for deterioration, etc. to evaluate how structures can be modified to increase effective lamprey control. Their program obviously wants to know how removal of barriers will affect sea lamprey distributions and abundance.   Program is participating in efforts to trap and sort only selective fish passage to allow fish other than lamprey to pass. But this still doesn't pass all fish types.

Tracy Galarowicz/CMU – Survey work was done in 2009/10 in 1st and 2nd order tributaries of Saginaw Bay. Sampled fish assemblages (100m transect, electrofishing) during spring and summer. Also collected information on abiotic factors, dredging history, and landscape variables, including distance from headwaters and distance from Lake Huron. Streams sampled were highly modified and channelized; many with very high summer temperatures. Collected yellow perch in very high abundances in spring (mar/apr) - Many undersized mature spawners. In 2012, will begin to evaluate when yellow perch show up, how long are they there and why they are there. Can provide more info on individual species numbers and distance upstream for these smaller streams.

Brent Murry/CMU – Evaluating fish passage associated with Saginaw bay tributary restoration in the Cass River and Shiawassee River. What species are or will use the rock ramp structures, especially walleye. In 2010 found 100,000s sucker eggs on mats below dam at Frankenmuth, also red horse. They are considering both positive and negatives of reconnections in the study. Are walleye able to cross rock ramps (series of weirs) at Chesaning SR. Designed to channel flow with 5 degree grade. Findings inconclusive so far, but not seeing much evidence of walleye migrating upstream. No known walleye eggs found above. Some fisherman reports of walleye above ramp. Walleye and white sucker eggs are being found below the ramp, but not above. Many found within rock ramps. One concern being evaluated is whether fish able to migrate back downstream over what might now be a more considerable barrier as water levels drop during summer (considering rock ramp, weirs, etc)? Future Study: Are rock ramps functioning as intended and what are the impacts of restoring connectivity. Often dams have been in place for close to 100 yrs. (thinking of changing fish assemblages and invasive species). Studying Cass (dam), Shiawassee (rock weir), Tittabawassee (dam), and Flint (free flowing). Spawing fish, tagging summer fish and looking at movement patterns and assemblage structure. Also studying otolith microchemistry – getting fingerprint of each river, which rivers are contributing most to bay populations. Major tributaries contributing what proportion of population in Saginaw Bay?

Andrea Ania/USFWS – Have been conducting aquatic invasive species fall sampling in Lake Huron for many years and that dataset includes many migratory species. Andrea is involved in the rock ramp evaluations that Brent Murry discussed. It is important to remember that fish can act as vectors of contaminants in Sag river watershed. We need to develop datasets to answer the question: What is the value of barrier removal in terms of quality habitat? If we're investing in barrier removal, it is important to know that there is suitable upstream habitat.

Dan Hayes/MSU – Dan may have some relevant data available. He has had a project evaluating sea lamprey barriers in which he sampled 25 streams w/ and 25 streams w/o barriers. Dan pointed out that use of raw numbers of fish caught without being relativized for effort can be somewhat meaningless (a comment on the migratory fish mapping project of which this gaps analysis is a part). Pointed out that there are some papers on modeling and predicting habitats with dam removal. Often our understanding of fish requirements is on the microhabitat scale, which doesn't transfer well to watershed scale. For other species, we know watershed scale/macrohabitat, but not the specific microhabitat. Survival and production in non-preferred habitat is also generally not documented. Challenges with understanding requirements of different fish species. It's also important to remember that dams are not just barriers to fish passage, but are also barrier to other things, including other animals, sediment transfer, nutrients, and other materials (e.g. woody debris).

Patrick Ertel/Huron Pines – Huron Pines is implementing watershed-wide road-crossing barrier assessments and are conducting detailed dam inventories. Inventories for the Au Sable have been completed, where they found lots of beaver dams not considered in other databases. Are evaluating coastal drainages that feed directly into Lake Huron; survey commenced today w/78 suspect barriers (identified through examination of aerial imagery). They have spatial data comparing state and federal databases and then showing road-crossing and other barriers that were not included. They are working on some barrier removal projects (and 16 replacements for fish passage) and are creating a guidebook for project manager in dam removal, which is set to come out this winter.

Matt Diebel – Work on a Great Lakes Aquatic Connectivity Project; creating common infrastructure for barrier data. Working to design a standardized road-crossing assessment protocol so that the same data can be started and managed together for analyses and prioritization. Matt developed a tool to quantify connectivity and prioritize barrier removal, including models to optimize improvement in connectivity for a given cost. Developing tools that will coordinate with ROADSOFT software to improve fish passage. Ultimately working toward barrier maps for the entire Great Lakes basin (w/o ground-truthing), with estimated passibility at road crossings. Estimates and related uncertainty will help to guide ground assessments. Mapping species specific habitat quality to assess value of dam removal, with emphasis on sturgeon and brook trout.

Evan Childress – Evan is a graduate student at U of Wisconsin working with Pete McIntyre. He is conducting road/stream assessment in Green bay, assessing pass-ability to evaluate connectivity for optimizing barrier removal. Conducted research on sucker migrations to ask whether suckers provide nutrient supplement to spawning habitat resulting in nutrient pulses, and algal and insect growth. Now his work is asking "Where do sucker migrations contribute nutrient subsidies that are important ecologically? " There should be a gradient from pristine areas where nutrient contributions are important to ag/cattle land where nutrient contributions are quickly swamped. Also examining other possible contributing factors, such as size of river.

Dan Oele– Dan is a graduate student at U of Wisconsin working with Pete McIntyre. He is researching northern pike migrations. In particular, he is asking whether northern pike return to the same areas to spawn? Are pike homing to specific spawning sites or are there other drivers for spawning migration? His research will include some habitat modeling.

Development of Conservation Priorities for Migratory, River-spawning Fishes in Lake Huron

Appendix 2

Priority reach and HUC10 watershed maps for Lake Huron migratory fish species based on a migratory index and expert review

Figures

Silver Lamprey (*Ichthyomyzon unicuspis*)

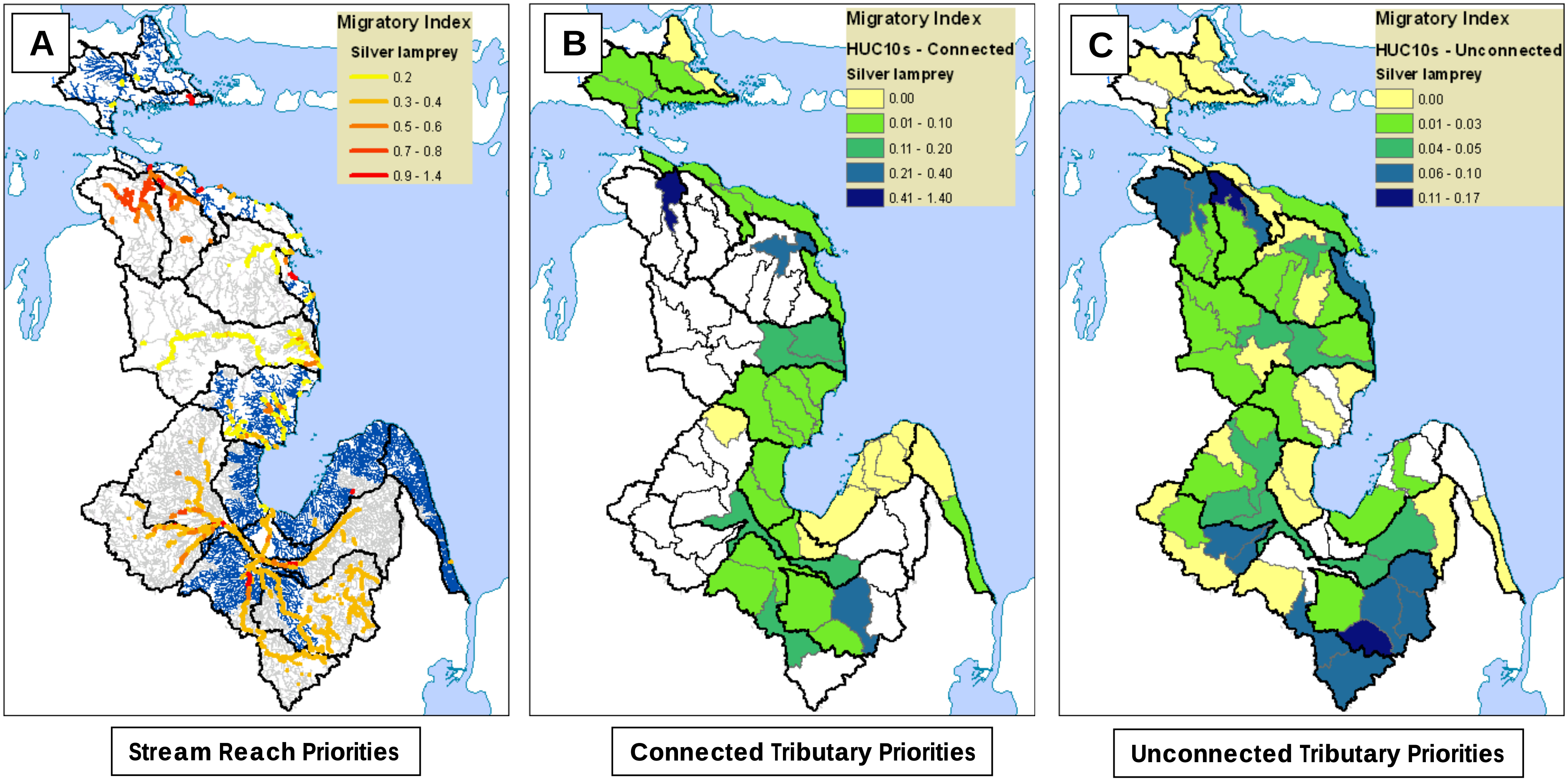


Figure 1. Tributaries important to Lake Huron silver lamprey for (A) specific stream locations, (B) watersheds based on streams connected to Lake Huron, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Silver lamprey habitat is widely distributed, but is most strongly associated with the Cheboygan River watershed and the southern portions of the Saginaw River watershed. The best potential (unconnected) habitat is in the Cheboygan River watershed and portions of the Saginaw River watershed.

Brook Trout (*Salvelinus fontinalis*)

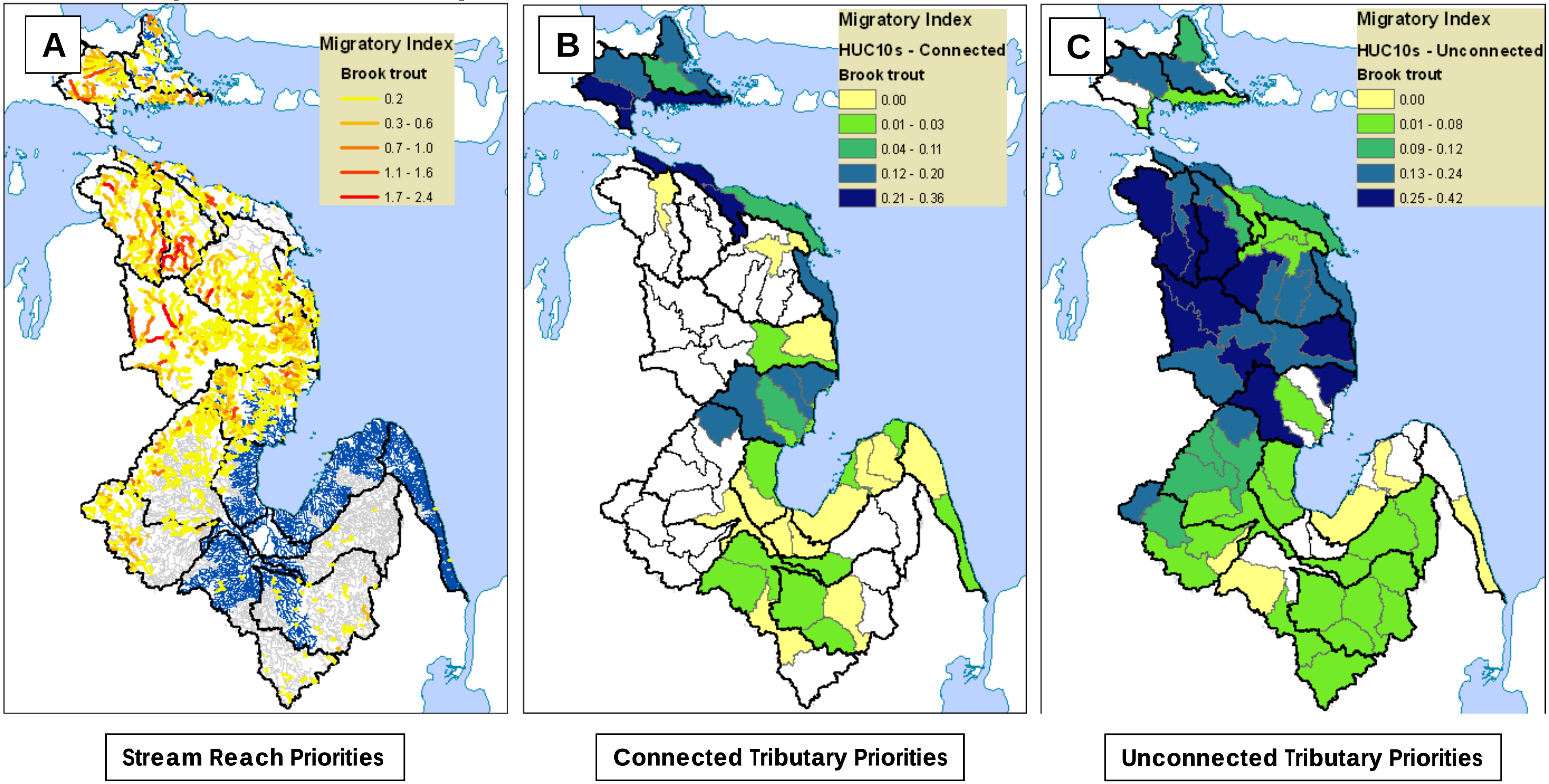


Figure 2. Tributaries important to Lake Huron brook trout for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Brook trout habitat is concentrated in the northern Lower Peninsula. Since maps A,B, and C primarily reflected inland brook trout populations, we concluded that the analyses were not effective for migratory river-spawning populations of Lake Huron brook trout. After consultation with regional experts, the watershed maps were redone manually using results from Enterline (2000) (Figure 3).

Brook Trout (*Salvelinus fontinalis*) – modified

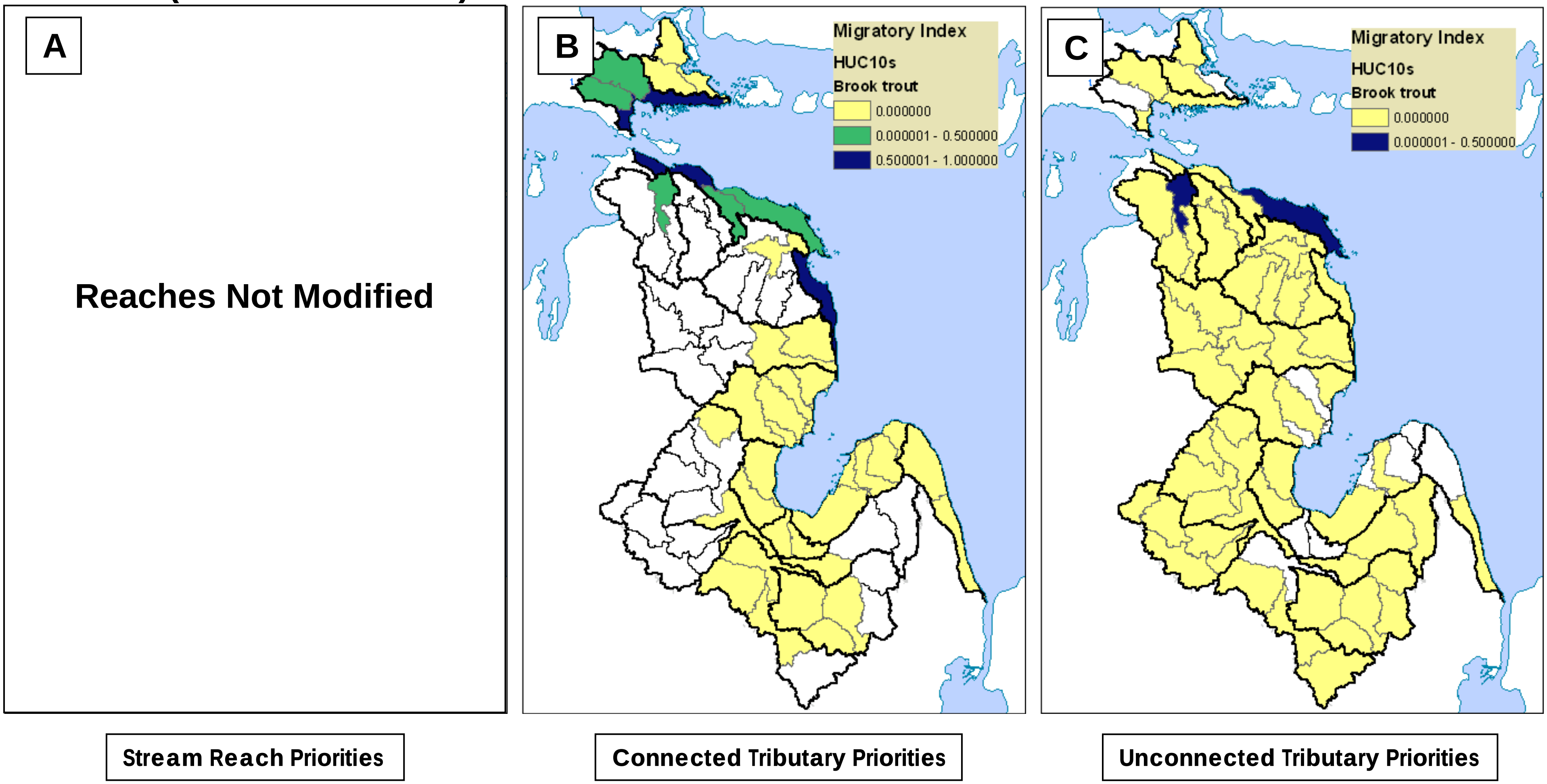


Figure 3. Brook trout maps from data analyses were biased toward inland populations (Figure 2 a-c), so priority tributaries for Lake Huron brook trout were mapped manually for (B) watersheds based on connected streams and (C) watersheds based on unconnected streams using results from Enterline (2000). These populations are concentrated in coastal streams in the Upper Peninsula and northern Lower Peninsula. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps.

*Black Redhorse (*Moxostoma duquesneii*)

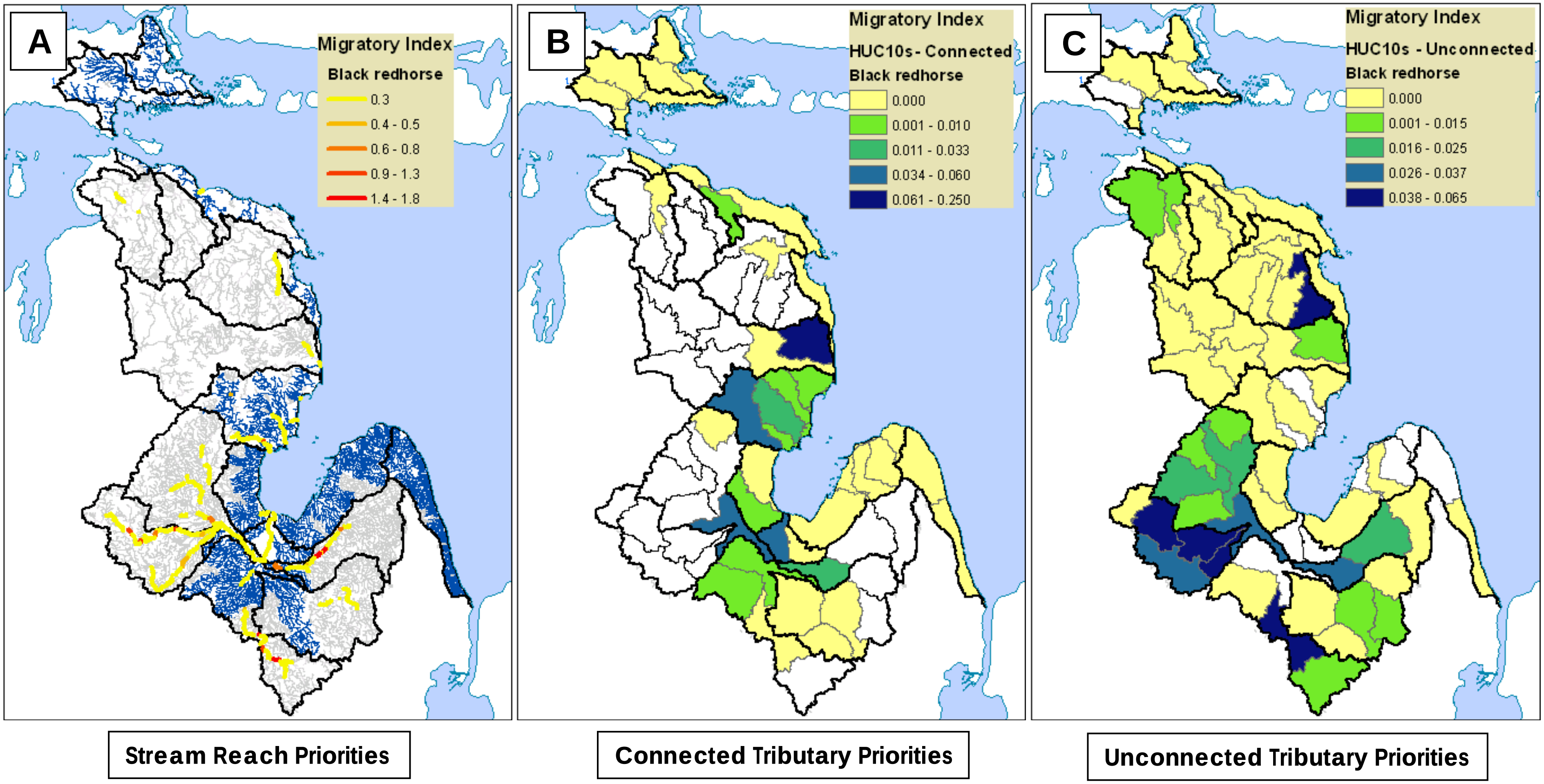


Figure 4. Tributaries important to Lake Huron black redhorse for (A) specific stream locations, (B) watersheds based on streams connected to Lake Huron, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Black redhorse are primarily associated with the Saginaw River and its tributaries. Experts reviewing preliminary analyses suggested that black redhorse are riverine and are not found in Lake Huron. This input corroborated with the data we assembled. We had no records of black redhorse from the lake and the majority of black redhorse records were above the lowest barrier. Therefore, black redhorse were not used in analyses to identify multi-species priority migratory fish tributaries.

*Black redhorse were not used in multi-species analyses because experts reviewing final products questioned their status as Lake Huron fish and none of the coastal data sources included records in Lake Huron.

Burbot (*Lota lota*)

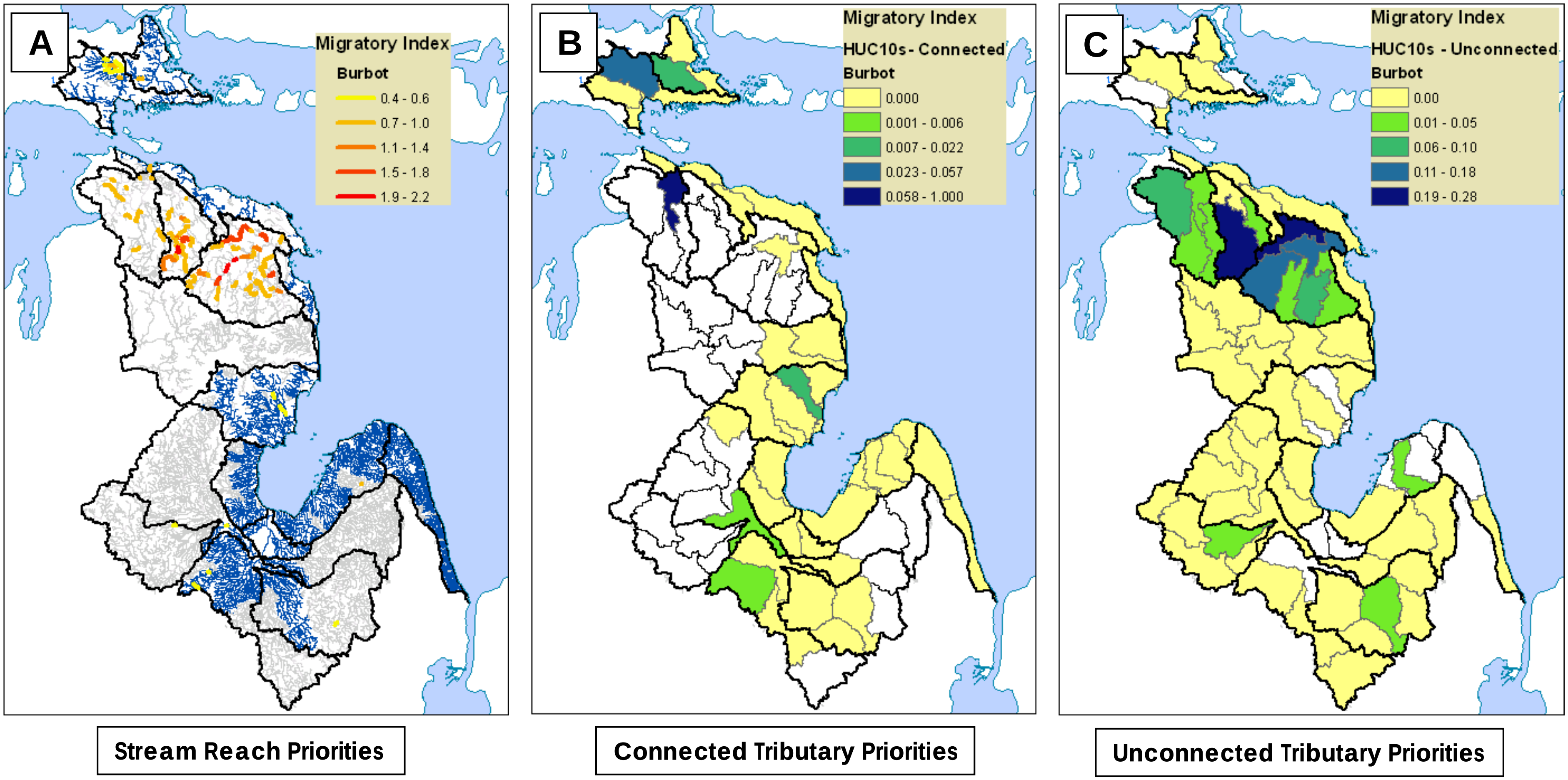


Figure 5. Tributaries important to Lake Huron burbot for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Burbot habitat is concentrated in northern Lake Huron, which reflects the fact that burbot are a cold water species. The best potential (unconnected) burbot habitat is in the Thunder Bay and Cheboygan River watersheds. Slight modifications were made to the connected tributary map, to reflect known current migratory burbot movement into the lower Thunder Bay River and Au Sable River to spawn (Figure 6).

Burbot (*Lota lota*) - Modified

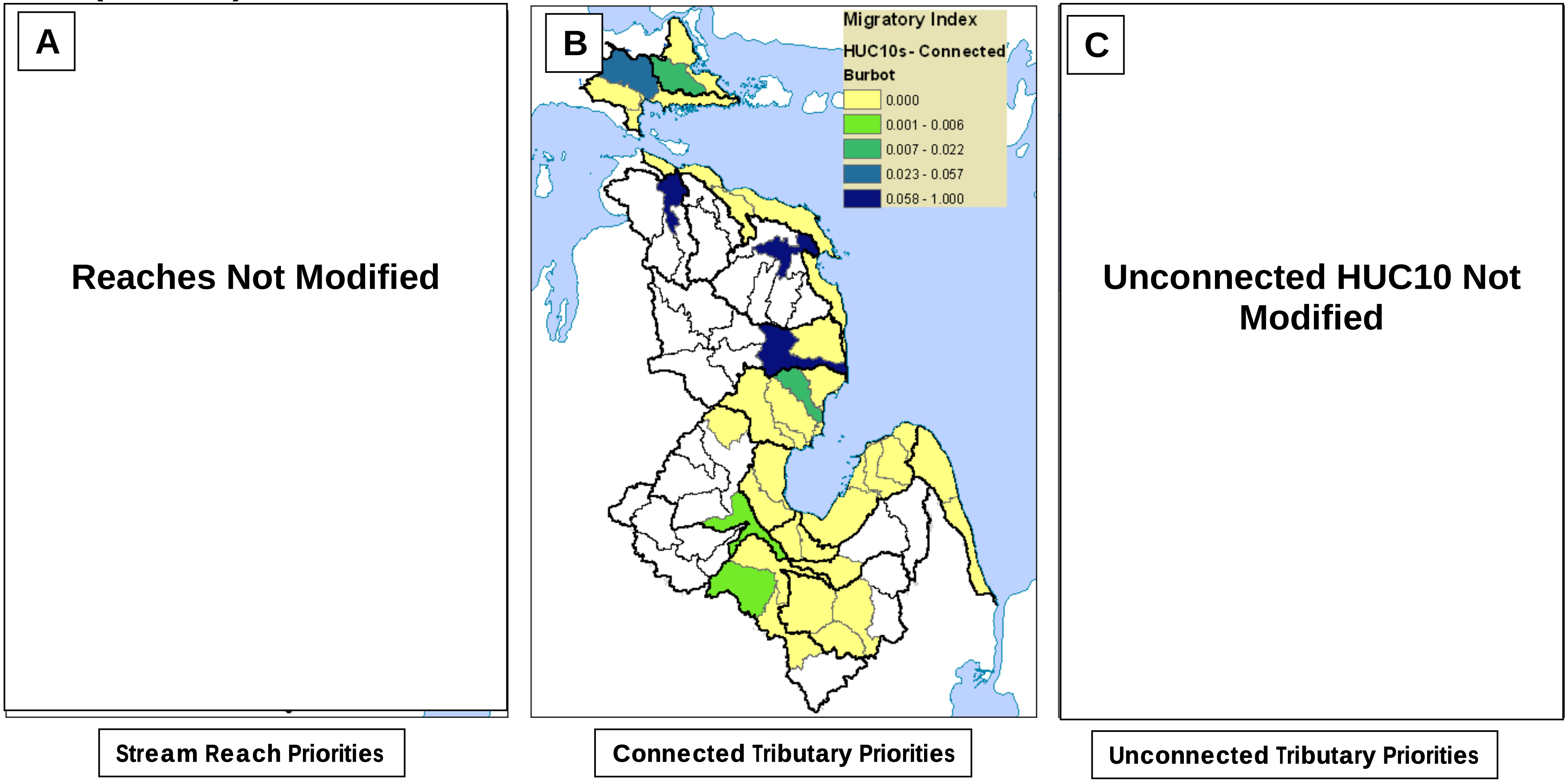


Figure 6. Tributaries important to Lake Huron burbot, with manual modification due to expert input, for (B) watersheds based on connected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Manual modifications were to reflect known current migratory burbot movement into the lower Thunder Bay River and Au Sable River to spawn. Connected habitat for Burbot is concentrated in northern Lake Huron in large tributaries—despite limited habitat available below the lowest barrier—and connected tributaries in the UP.

Channel Catfish (*Ictalurus punctatus*)

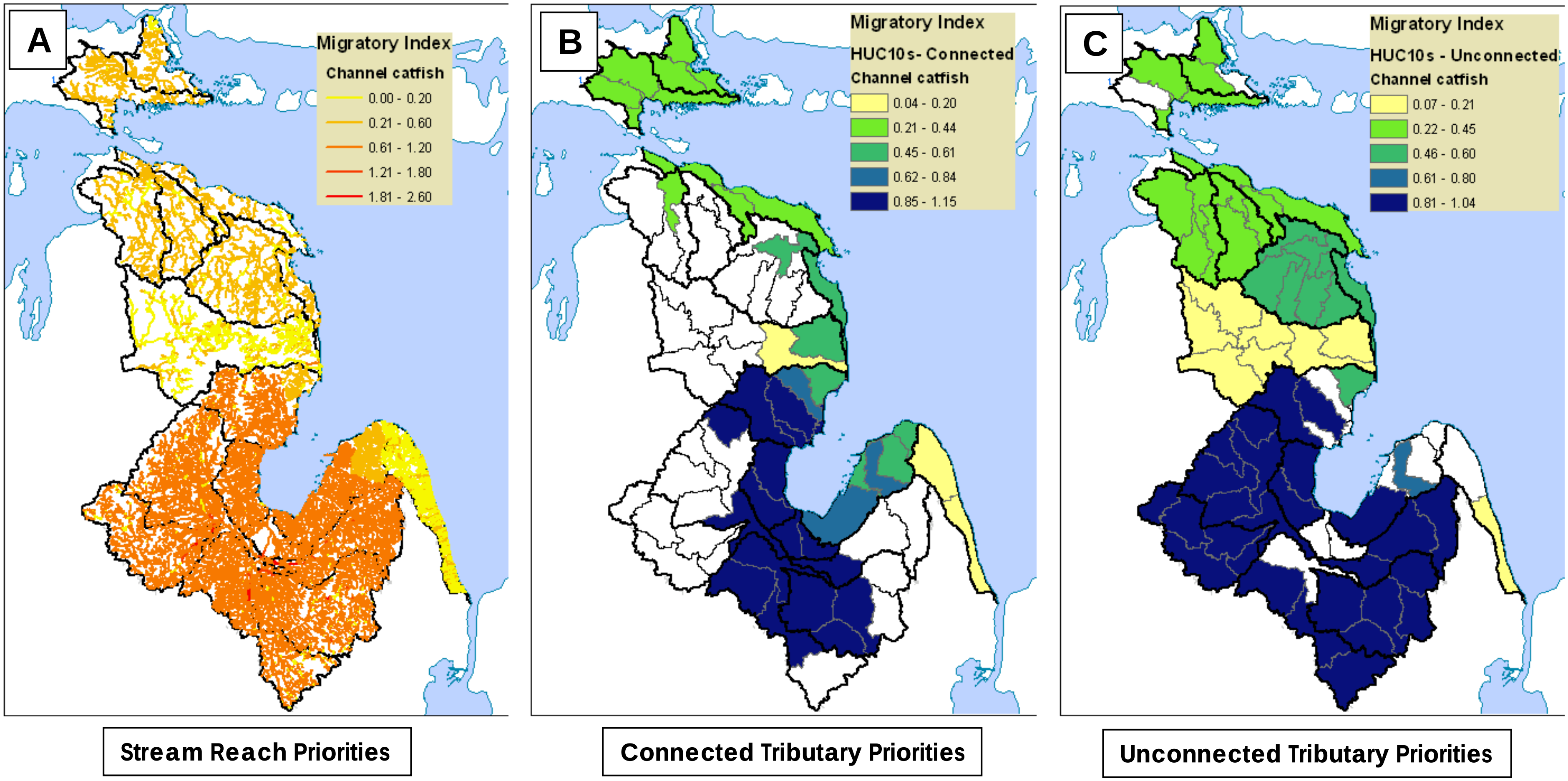


Figure 7. Tributaries important to Lake Huron channel catfish for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Analyses indicated that channel catfish habitat is widespread, but most highly weighted toward Saginaw Bay. However, regional experts indicated that these distributions seemed to substantially overrepresent channel catfish habitat, with whole watersheds included where they have never been documented. We reviewed the original data and found those areas were being driven by Aquatic Gap predicted areas. Since experts felt strongly that much of the habitat being predicted was not appropriate, we recalculated the Index without aquatic Gap (Figure 8).

Channel Catfish (*Ictalurus punctatus*) - modified

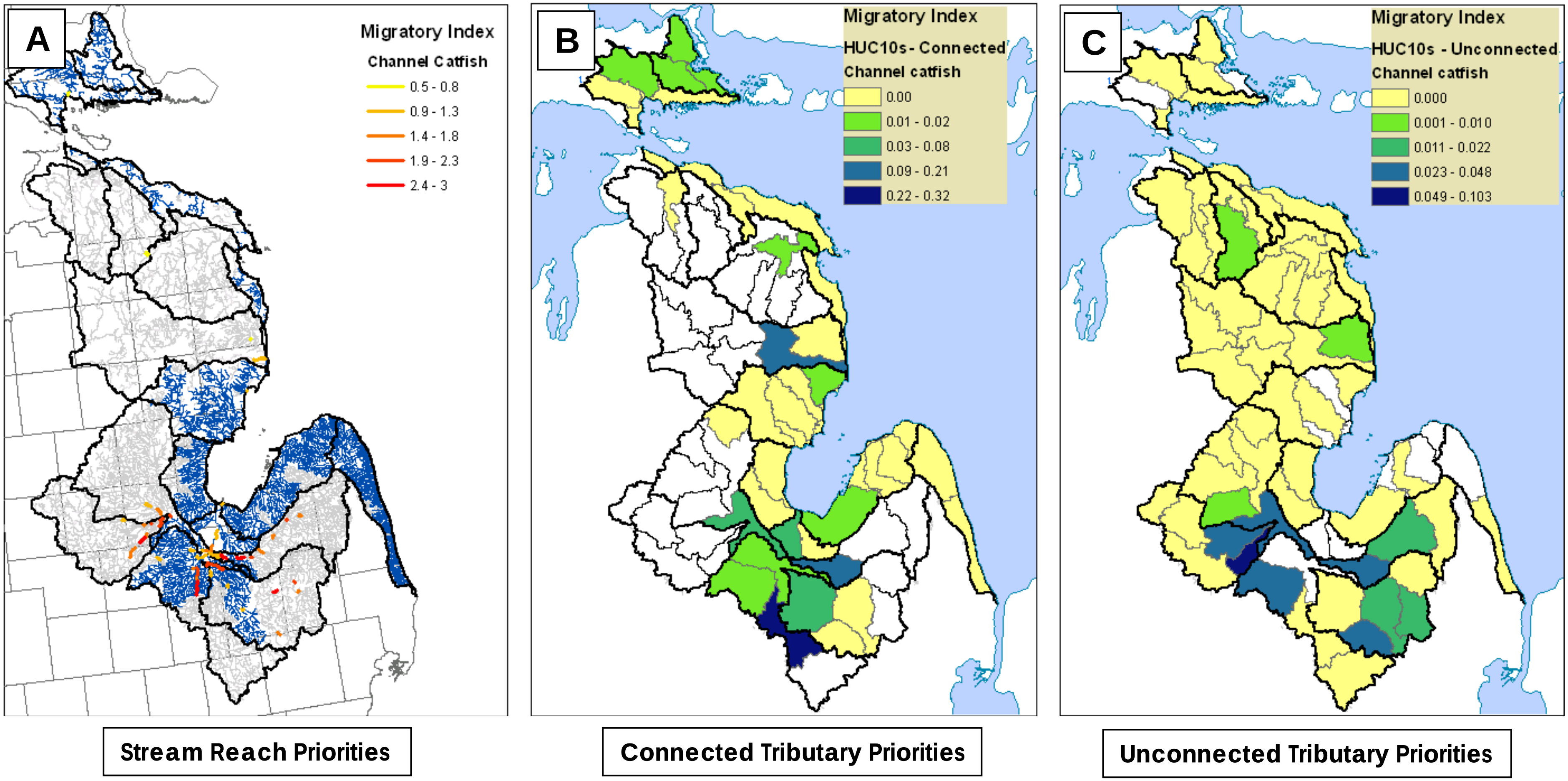


Figure 8. Tributaries important to Lake Huron channel catfish, after modification by removing Aquatic Gap data from the analysis as recommended during expert review, for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Channel catfish priority tributaries—connected and unconnected—are concentrated in the Saginaw River system.

Channel Darter (*Percina copelandi*)

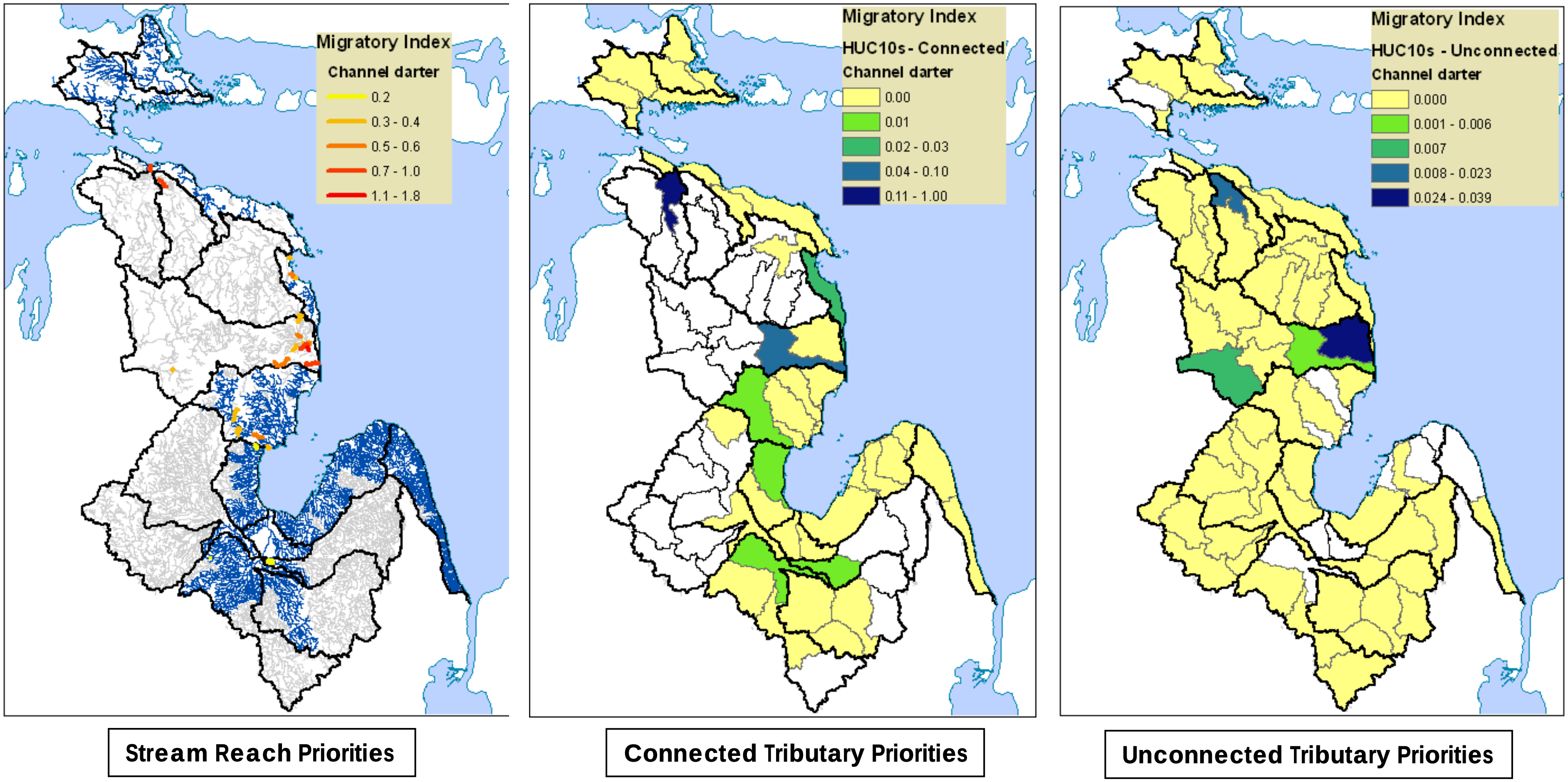


Figure 9. Tributaries important to Lake Huron channel darters for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Analyses indicate that channel darters are quite rare in Lake Huron and their tributary habitat is scattered from the Cheboygan River to the Shiawassee Flats area in the Saginaw River watershed. The best potential (unconnected) channel darter habitat is in the Au Sable River watershed.

Freshwater Drum (*Aplodinotus grunniens*)

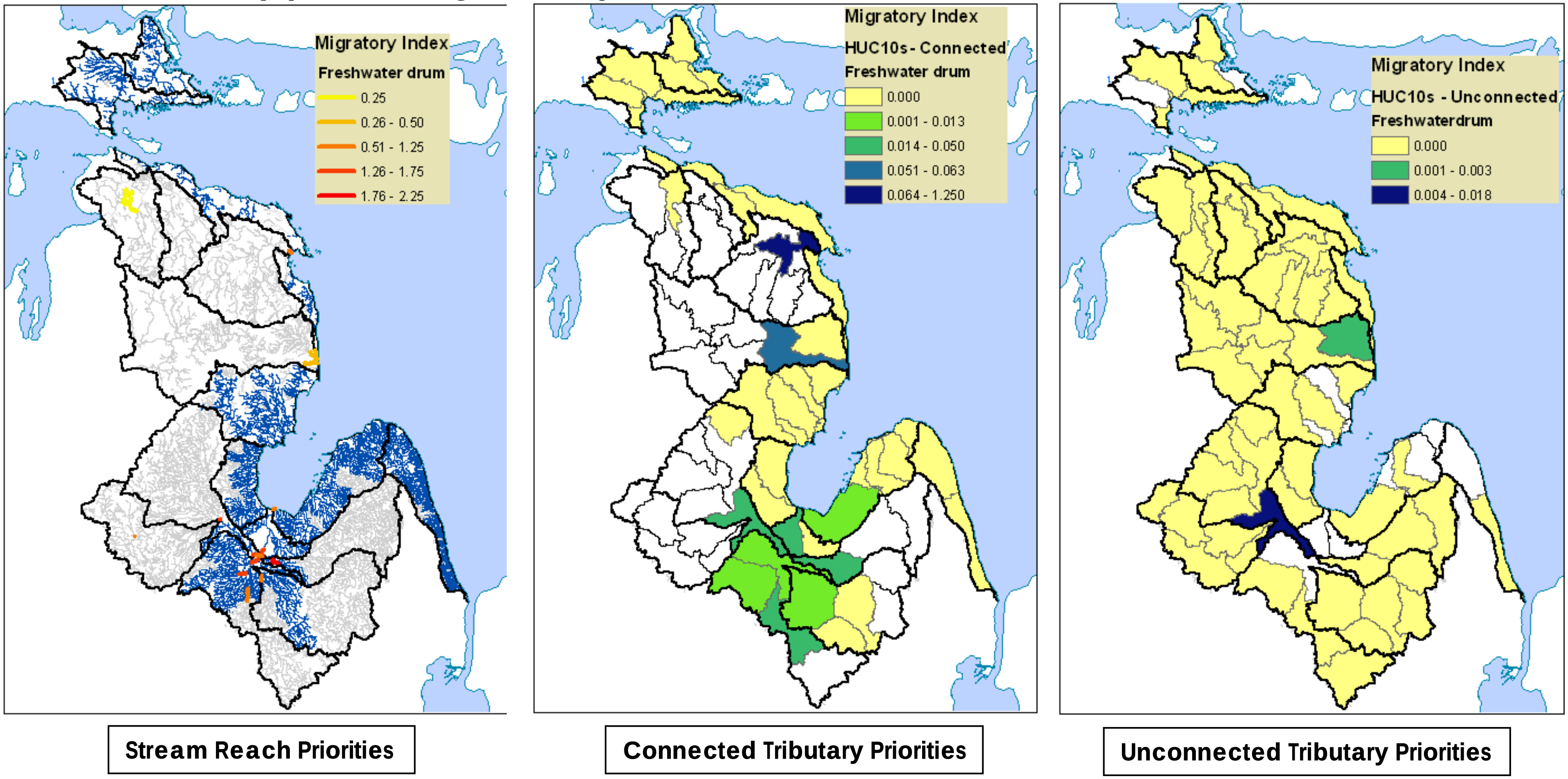


Figure 10. Tributaries important to Lake Huron freshwater drum for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Analyses indicate that freshwater drum are concentrated in the Saginaw River watershed, but that the lower Thunder Bay and Au Sable Rivers have quality freshwater drum spawning habitat. The best potential (unconnected) freshwater drum habitat is in the Tittabawassee River.

Longnose Gar (*Lepisosteus osseus*)

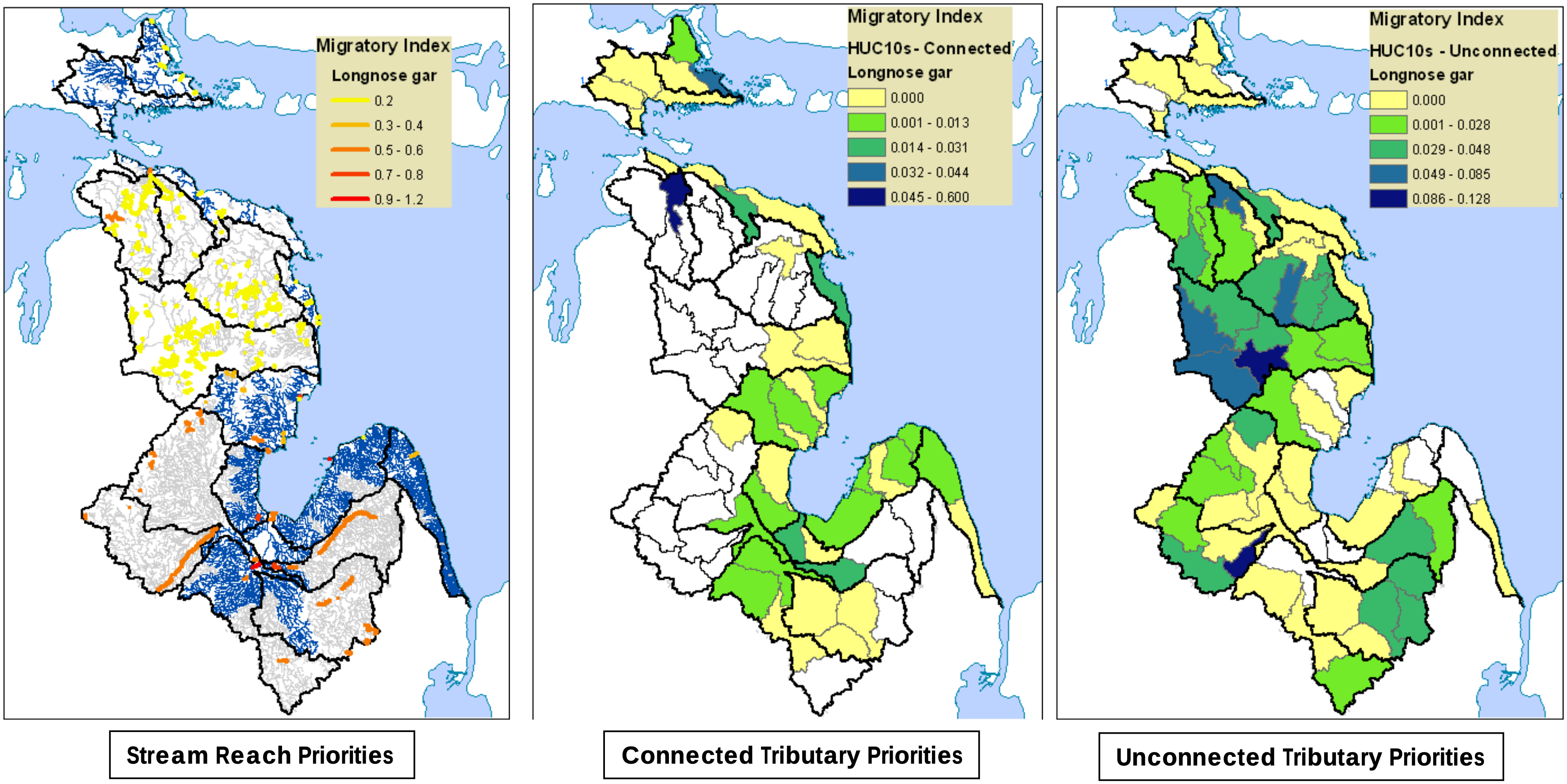


Figure 11. Tributaries important to Lake Huron longnose gar for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Analyses indicate that longnose gar habitat is widespread throughout the basin, but it most strongly concentrated in the Cheboygan and Au Sable River watersheds. However, regional experts indicated that these distributions seemed to substantially overrepresent longnose gar habitat, with whole watersheds included where they have never been documented. We reviewed the original data and found those areas were being driven by Aquatic Gap predicted areas. Since experts felt strongly that much of the habitat being predicted was not appropriate, we recalculated the Index without aquatic Gap (Figure12).

Longnose Gar (*Lepisosteus osseus*) – modified after expert review

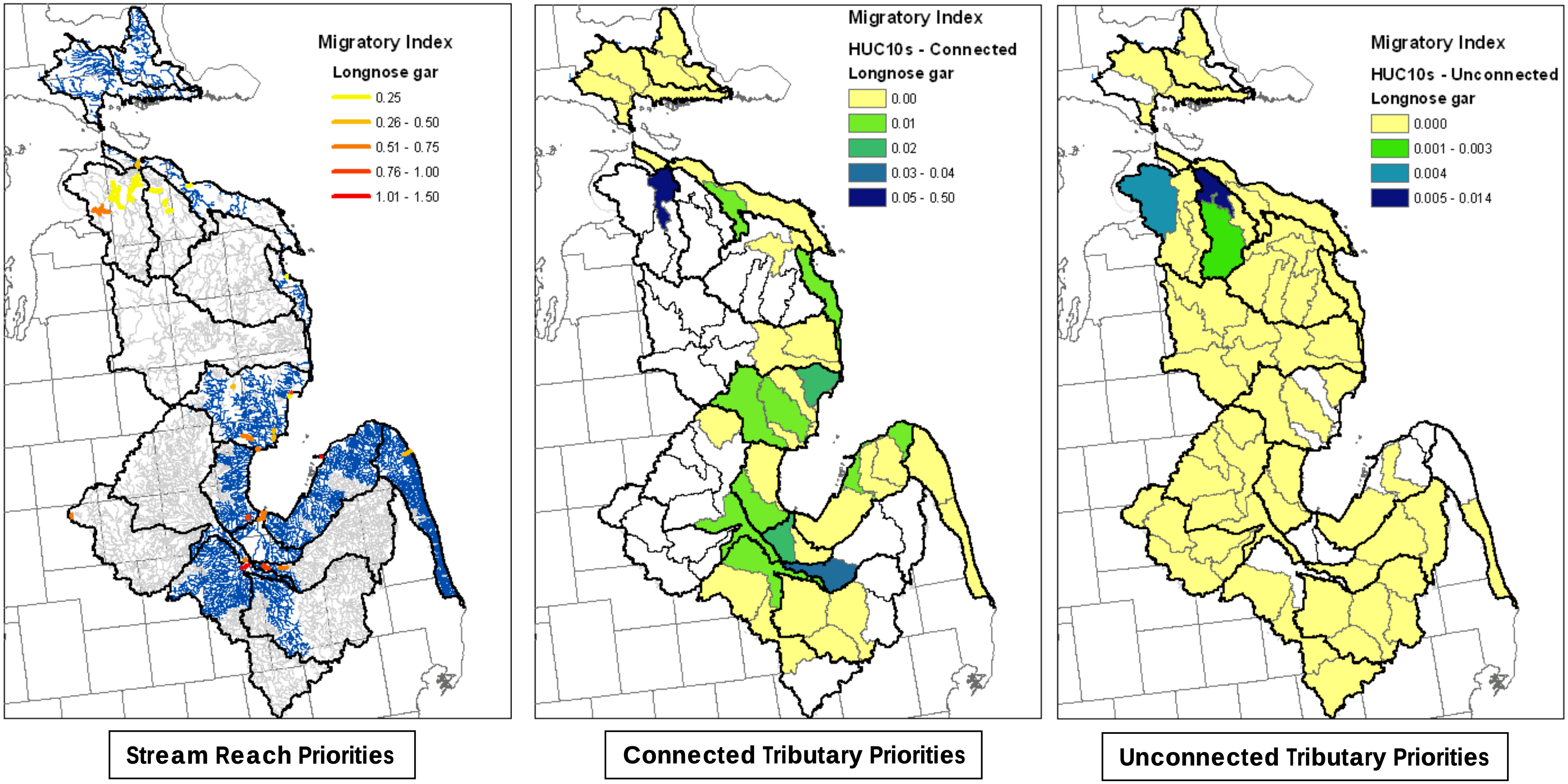


Figure 12. Tributaries important to Lake Huron longnose gar, after modification by removing Aquatic Gap data from the analysis--as recommended during expert review, for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Longnose gar priority areas are concentrated in the Cheboygan River watershed and Saginaw Bay tributaries, particularly the Saginaw River and the Shiawassee Flats area immediately upstream at the confluence of several major tributaries.

Lake Trout (*Salvelinus namaycush*)

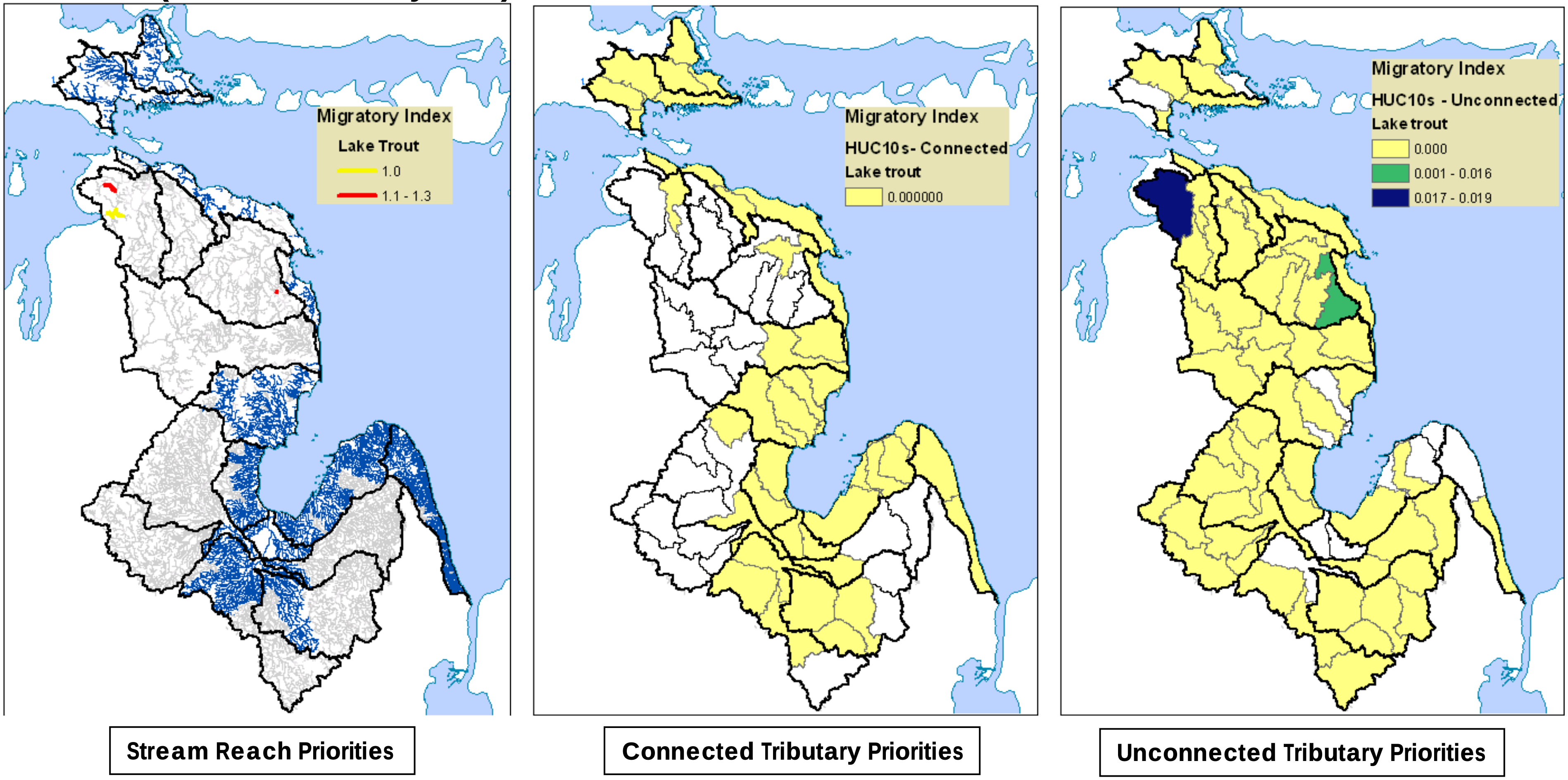


Figure 13. Tributaries important to Lake Huron lake trout for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Lake trout habitat is in the Burt Lake watershed in the Cheboygan River watershed and the Lower South Branch of the Thunder Bay River watershed. However, experts pointed out that the survey data sources used in our analyses are not particularly effective at sampling species like lake trout and there are known lake trout spawning areas that were not mapped. Therefore, modifications were made to the watershed maps to reflect known current migratory lake trout spawning areas or habitat that would provide good spawning habitat, if connected (Figure 14).

Lake Trout (*Salvelinus namaycush*) – modified after expert review

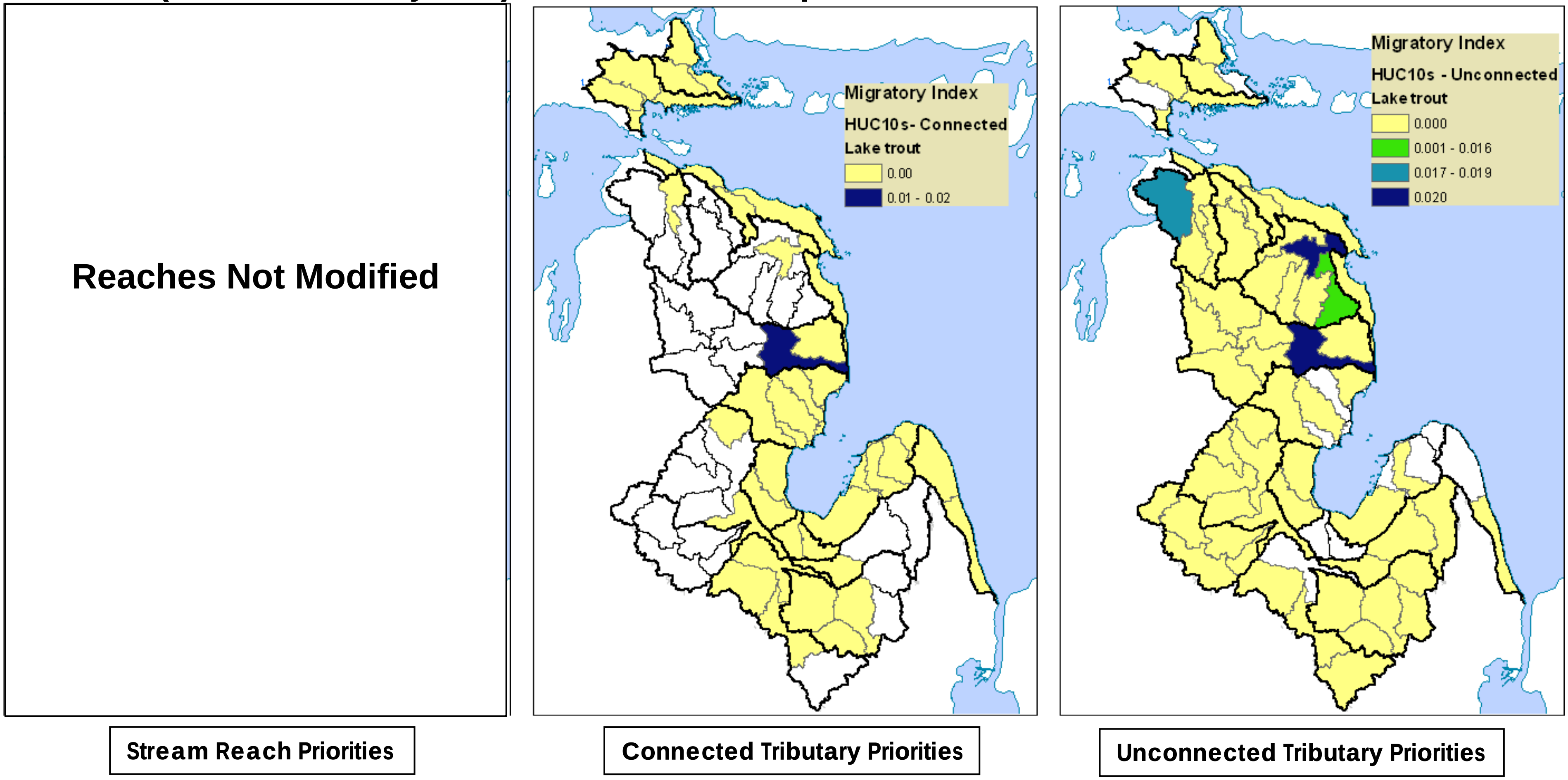


Figure 14. Tributaries important to Lake Huron lake trout, with manual modification due to expert input, for (B) watersheds based on connected streams and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Manual modifications reflect known current migratory lake trout movement into the lower Au Sable River to spawn and additional spawning habitat within the Au Sable and the lower nine miles of the Thunder Bay River above the lowest dam.

Lake Whitefish (*Coregonus clupeaformis*)

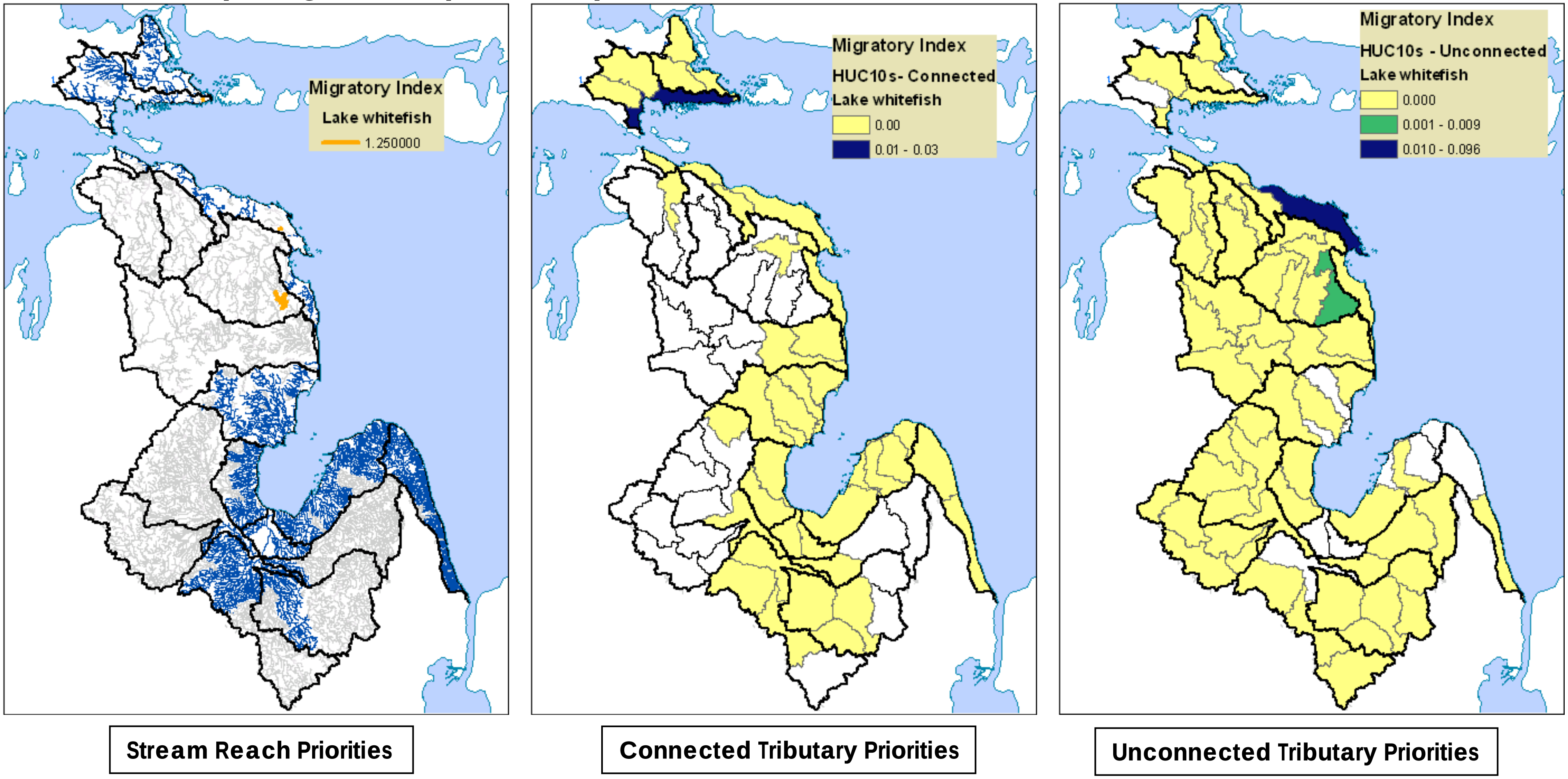


Figure 15. Tributaries important to Lake Huron lake whitefish for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Analyses indicate that Lake whitefish habitat occurs in scattered locations in northern Lake Huron. However, experts pointed out that the survey data sources used in our analyses are not particularly effective at sampling species like lake whitefish and there are known lake whitefish spawning areas that were not mapped. Therefore, modifications were made to the watershed maps, to reflect known current migratory lake whitefish spawning areas or habitat that would provide good spawning habitat, if connected (Figure 16).

Lake Whitefish (*Coregonus clupeaformis*) – modified after expert review

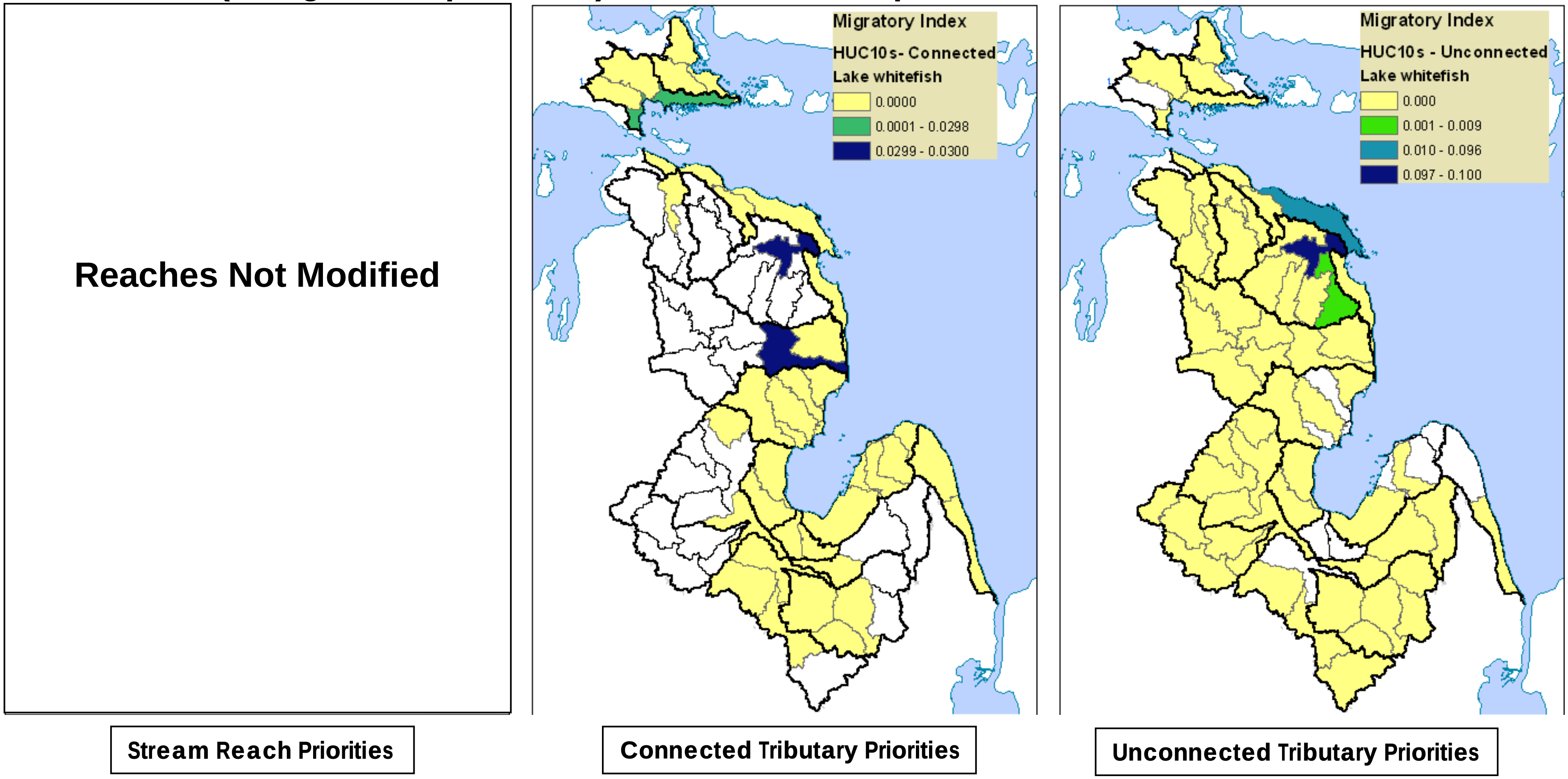
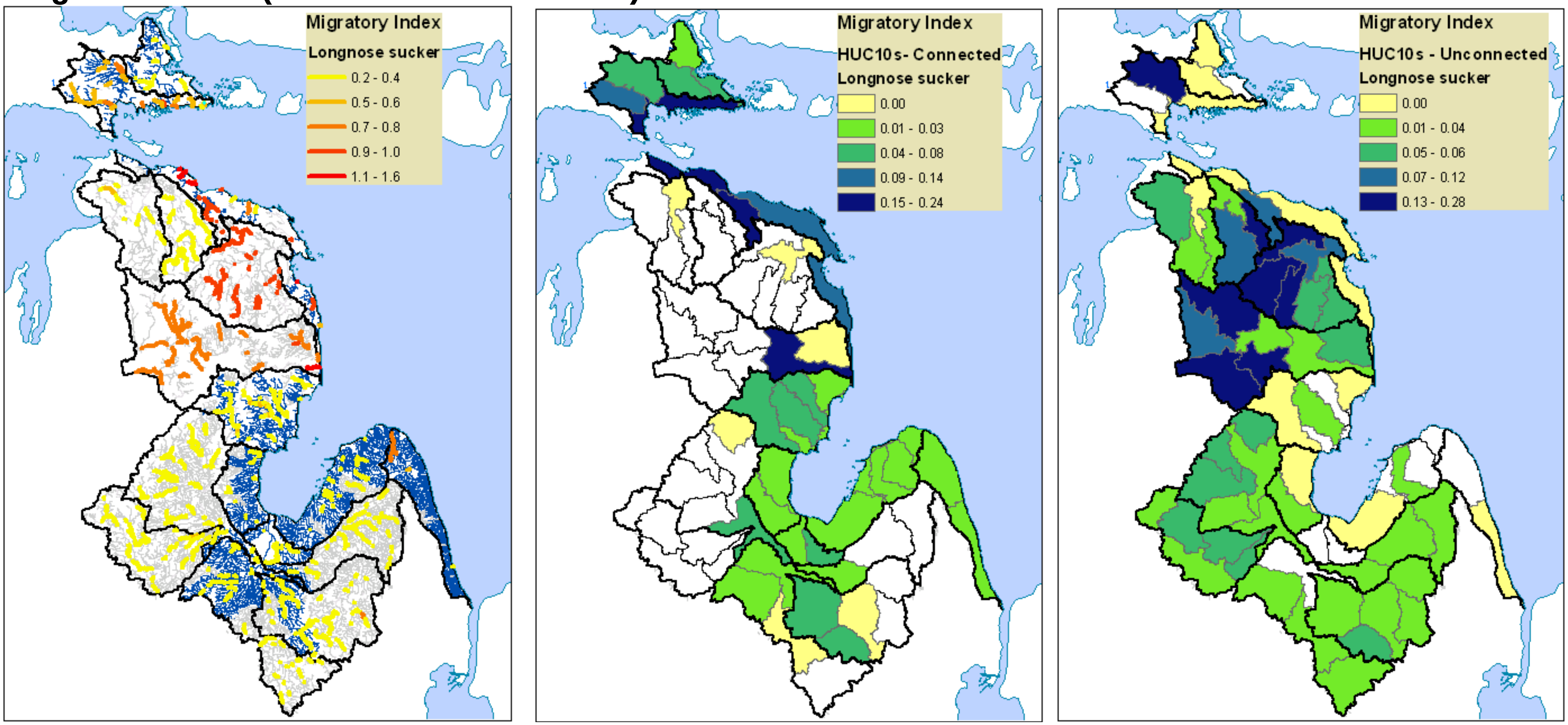


Figure 16. Tributaries important to Lake Huron lake whitefish, with manual modification due to expert input, for (B) watersheds based on connected streams and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Manual modifications reflect known spawning activity in the lower Au Sable and Thunder Bay Rivers to spawn and additional spawning habitat within the lower nine miles of the Thunder Bay River above the lowest dam.

Longnose Sucker (*Catostomus catostomus*)



Stream Reach Priorities | **Connected Tributary Priorities** | **Unconnected Tributary Priorities**

Figure 17. Stream reaches important to Lake Huron longnose sucker for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Longnose sucker habitat is broadly distributed within the Lake Huron basin, but the tributaries in the northern lower Peninsula and Upper Peninsula offer better habitat for them, including both connected and unconnected tributaries. However, regional experts indicated that these distributions seemed to substantially overrepresent longnose sucker habitat, with whole watersheds included where they have never been documented, particularly in inland watersheds not close to Lake Huron. We reviewed the original data and found those areas were being driven by Aquatic Gap predicted areas. Since experts felt strongly that much of the habitat being predicted was not appropriate, we recalculated the Index without aquatic Gap (Figure 18).

Longnose Sucker (*Catostomus catostomus*) – modified after expert review

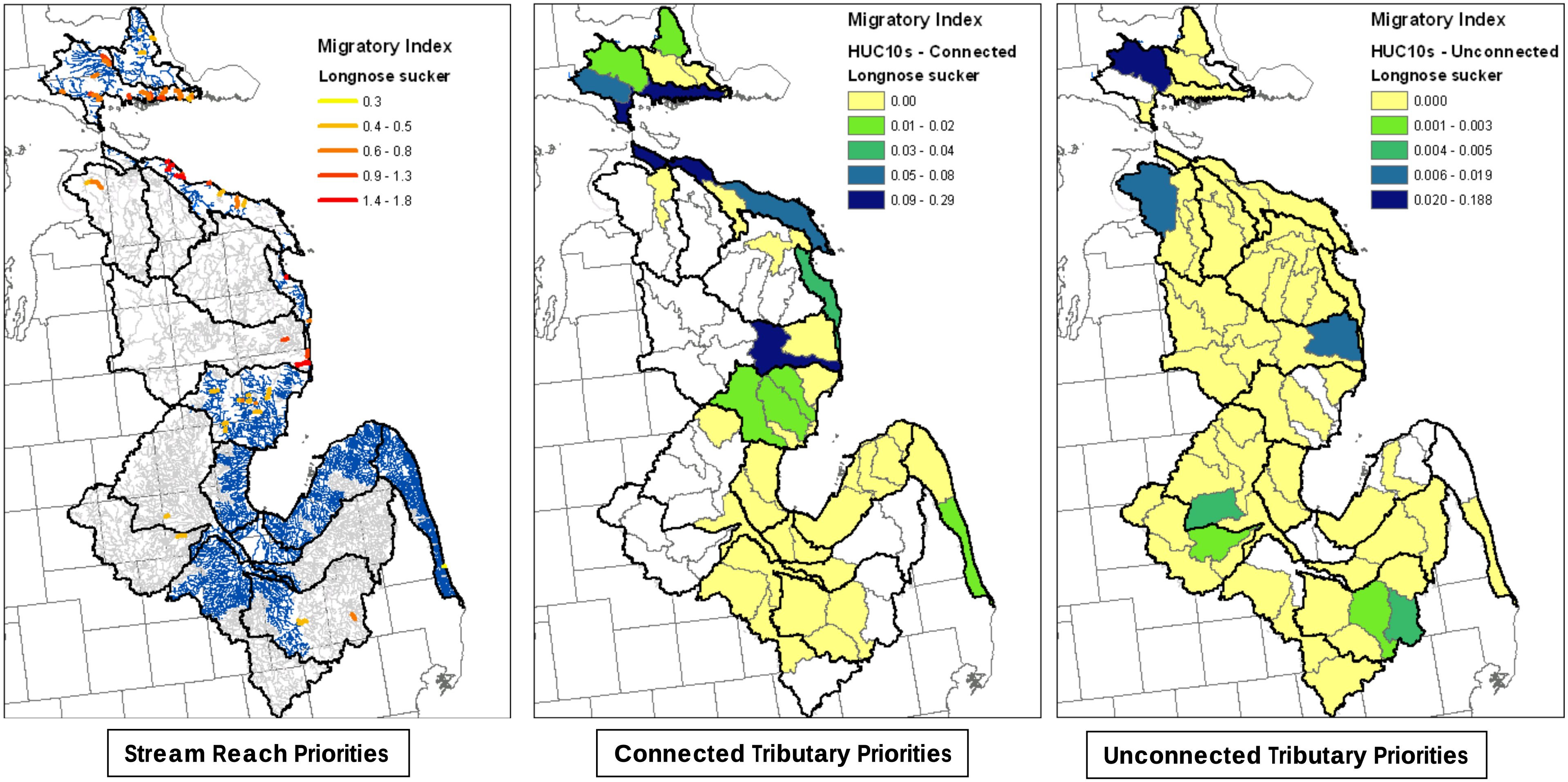


Figure 18. Tributaries important to Lake Huron longnose sucker, after modification by removing Aquatic Gap data from the analysis--as recommended during expert review, for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Longnose sucker habitat is widely distributed, but index scores are higher in the northern portions of Lake Huron. The highest scores tend to be in coastal tributaries, except the lower Au Sable River. The scores are similar to the original analysis, but generally do not include far inland tributaries, except in the Saginaw River watershed.

Mooneye (*Hiodon tergisus*)

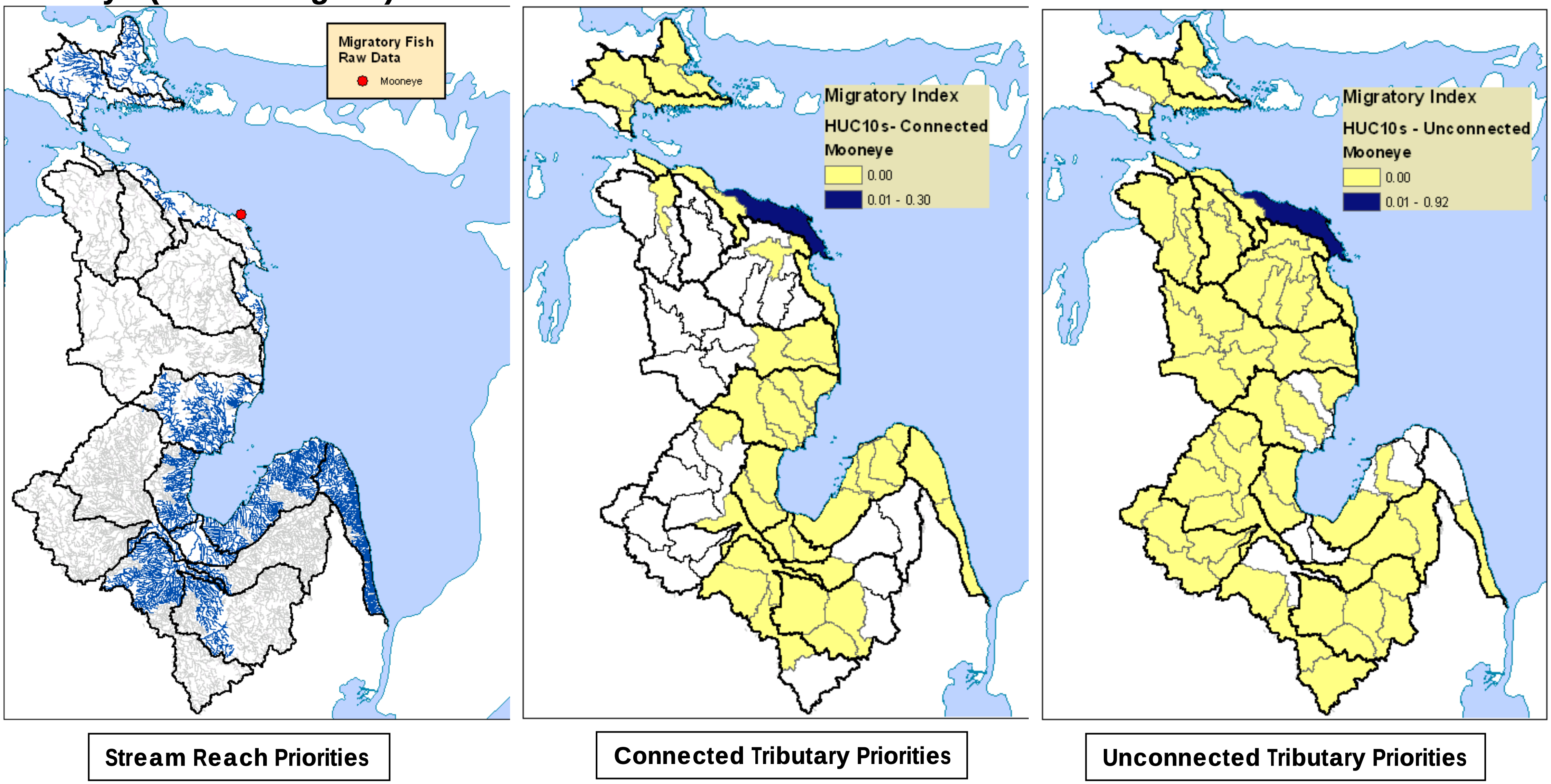


Figure 19. Tributaries important to Lake Huron mooneye for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. The data assembled for analyses included no stream records for mooneye. The only record of mooneye was in Lake Huron north of Thunder Bay. The coastal analysis only associated mooneye with the watershed for the adjacent smaller coastal streams. Experts agreed that these coastal tributaries were not the historic habitat of mooneye in Lake Huron, since mooneye generally only inhabit very large rivers and their interconnecting lakes (Becker 1983). Since it is unclear where Lake Huron mooneye populations would have occurred historically (Saginaw River?, St. Mary's River?, Thunder Bay River?), no priority mooneye watersheds were included in the multi-species prioritization.

Muskellunge (*Esox masquinongy*)

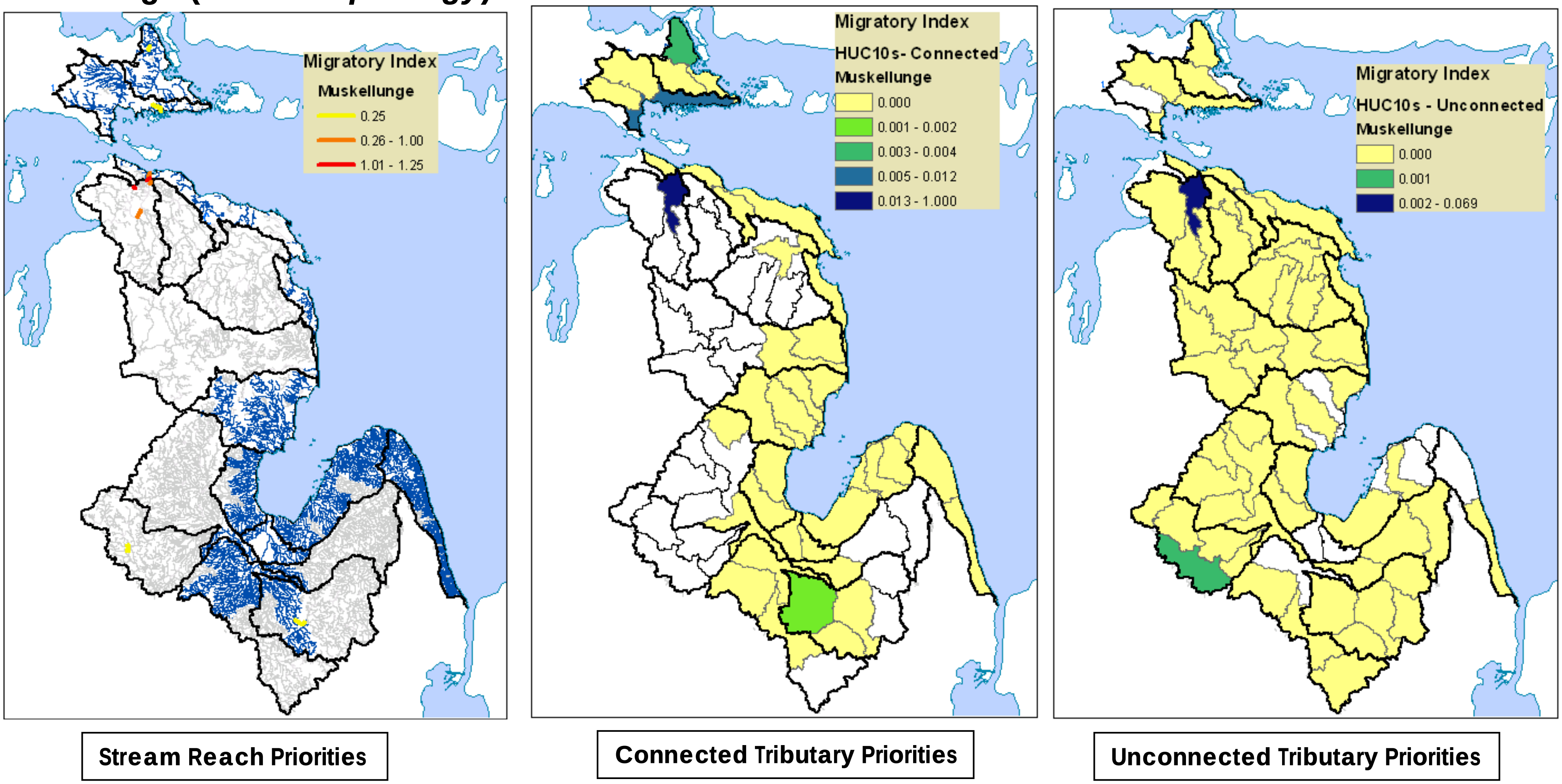


Figure 20. Tributaries important to Lake Huron muskellunge for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Muskellunge habitat is scattered across Lake Huron. Slight modifications were made to the unconnected tributary map, to reflect known muskellunge habitat in the Cheboygan River basin (Figure 21).

Muskellunge (*Esox masquinongy*) – modified after expert review

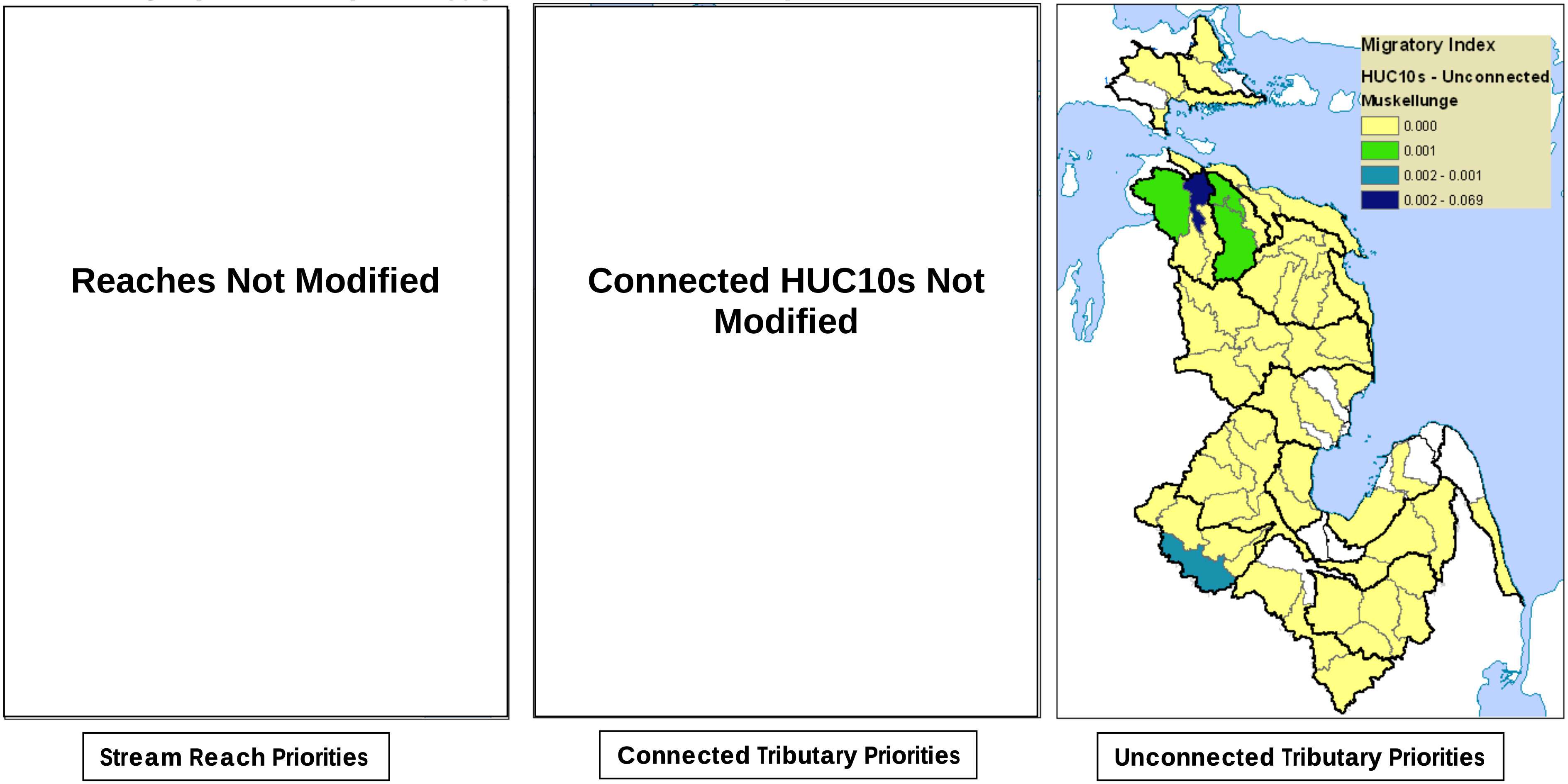
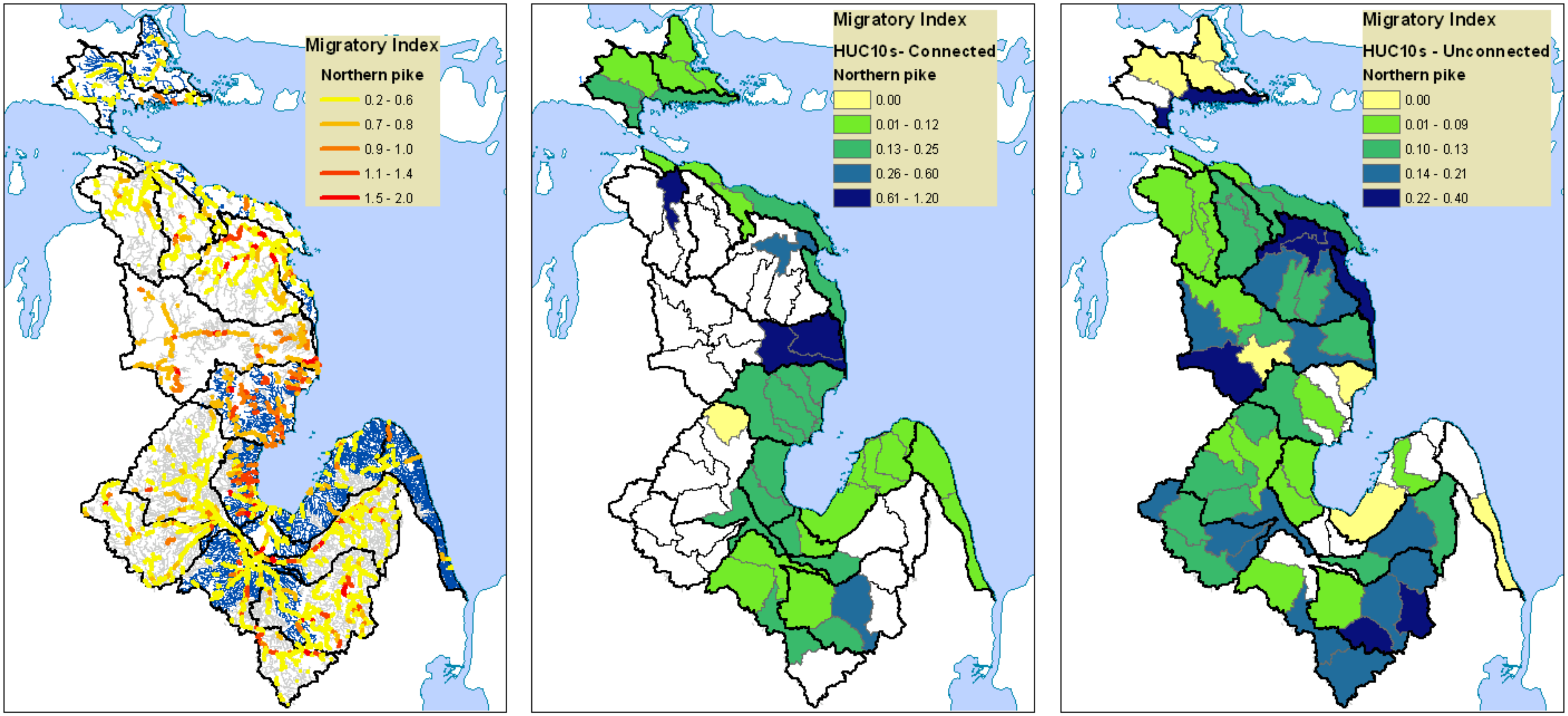


Figure 21. Tributaries important to Lake Huron muskellunge, with manual modification due to expert input, for (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Manual modifications were to reflect known muskellunge habitat in the Cheboygan River watershed. Potential (unconnected) habitat for Lake Huron muskellunge is primarily in the Cheboygan River watershed.

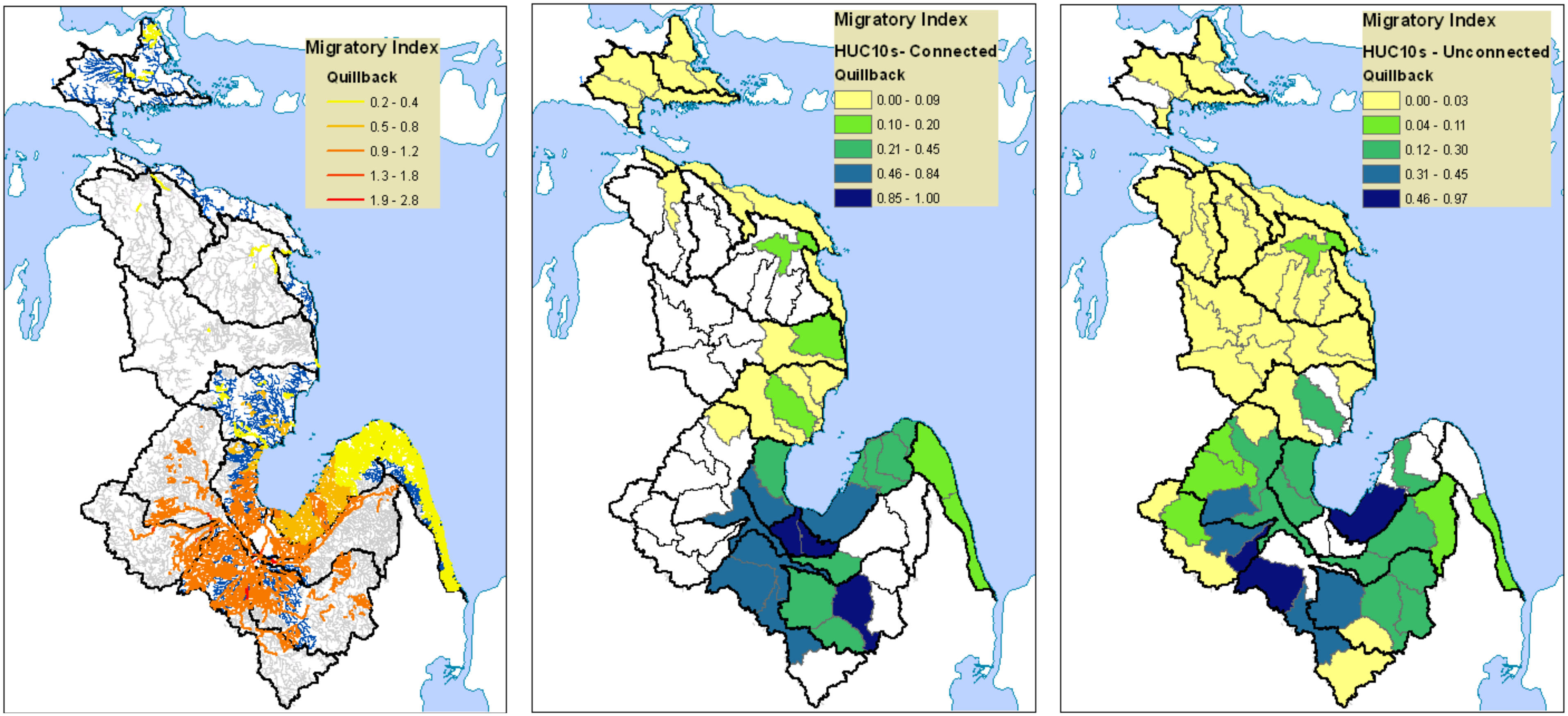
Northern Pike (*Esox lucius*)



Stream Reach Priorities | **Connected Tributary Priorities** | **Unconnected Tributary Priorities**

Figure 22. Tributaries important to Lake Huron northern pike for (A) specific stream locations, (B) watersheds based on streams connected to Lake Huron, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Northern pike habitat is widely distributed across the Lake Huron basin.

Quillback (*Carpiodes cyprinus*) – With GAP



Stream Reach Priorities | **Connected Tributary Priorities** | **Unconnected Tributary Priorities**

Figure 23. Tributaries important to Lake Huron quillback for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Analyses indicated that quillback are widely distributed, but their habitat is concentrated in Saginaw Bay. However, regional experts indicated that these distributions seemed to substantially overrepresent quillback habitat, with whole watersheds included where they have never been documented. We reviewed the original data and found those areas were being driven by Aquatic Gap predicted areas. Since experts felt strongly that much of the habitat being predicted was not appropriate, we recalculated the Index without aquatic Gap (Figure 24).

Quillback (*Carpiodes cyprinus*) – Modified, Without GAP

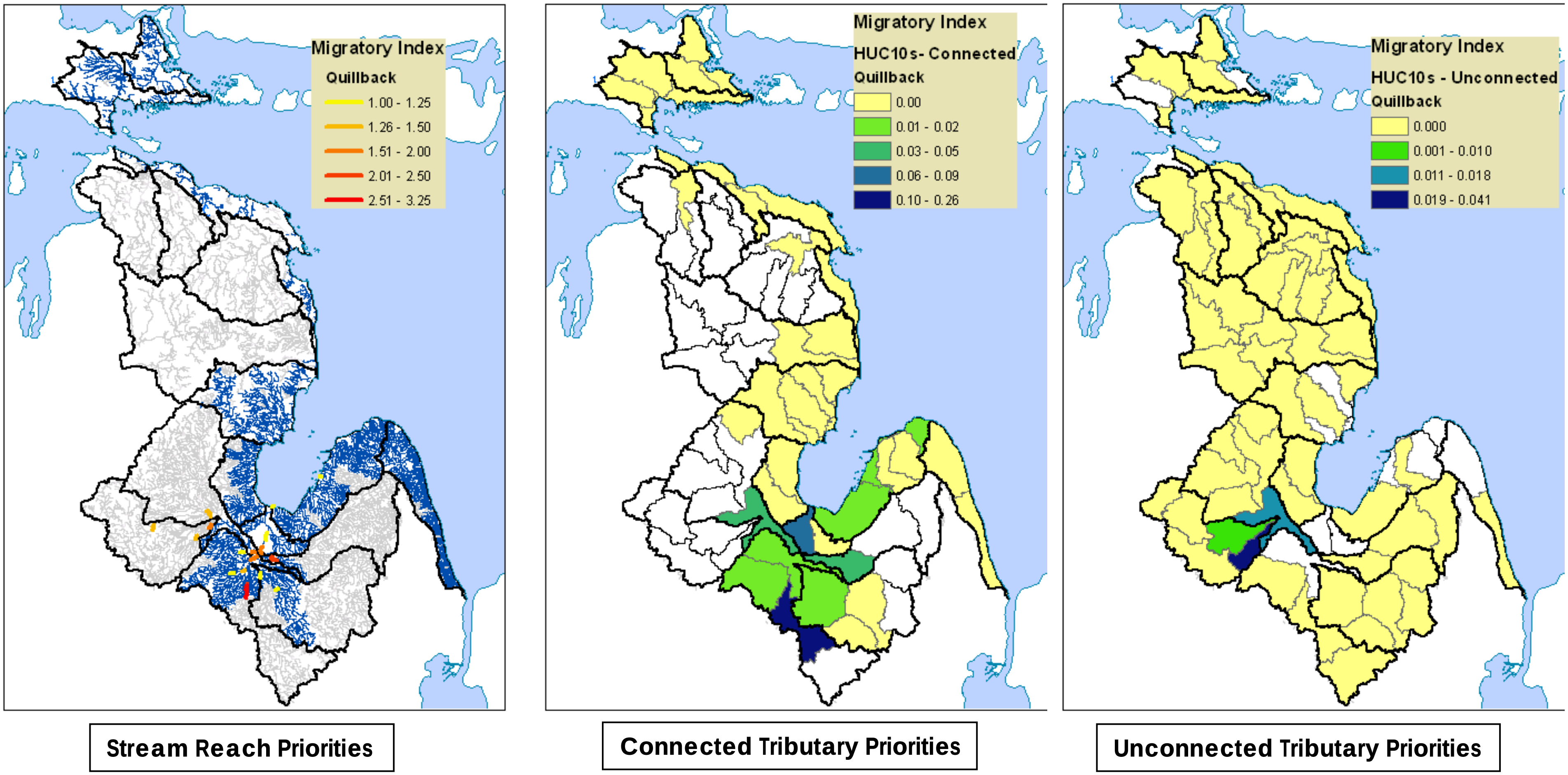


Figure 24. Tributaries important to Lake Huron quillback, after modification by removing Aquatic Gap data from the analysis as recommended during expert review, for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Following removal of Aquatic Gap from the analysis, quillback priority tributaries were entirely within the Saginaw Bay drainage. The best potential (unconnected) habitat is in the Tittabawassee and Pine Rivers.

River Darter (*Percina shumardi*)

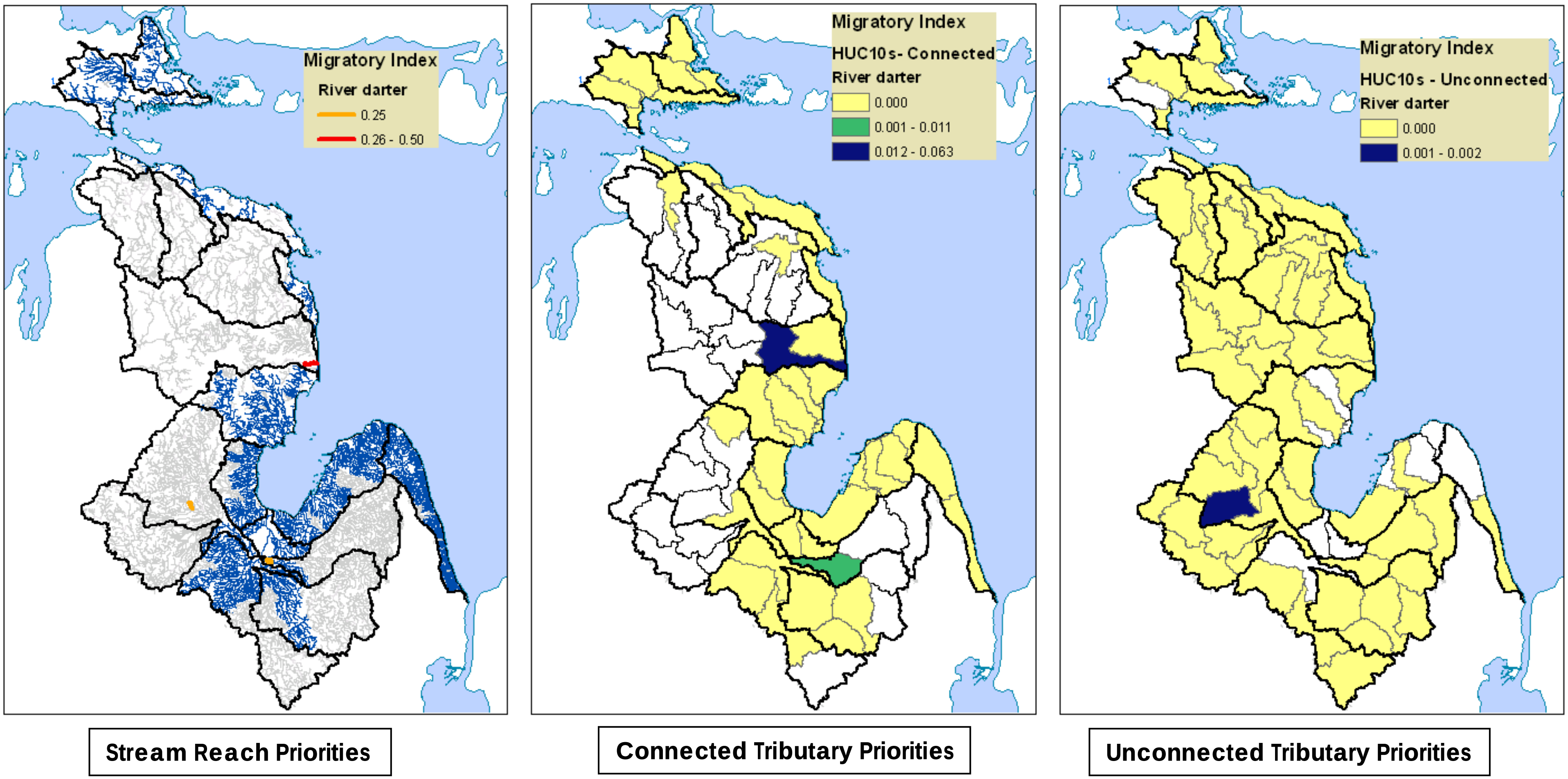


Figure 25. Tributaries important to Lake Huron river darters for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. River darters are very rare in the Lake Huron basin. Connected areas that are important to them are the lower Au Sable River and the lower Flint River. The Chippewa River watershed would provide habitat to river darters, if connected to Lake Huron.

Round Whitefish (*Prosopium cylindraceum*)

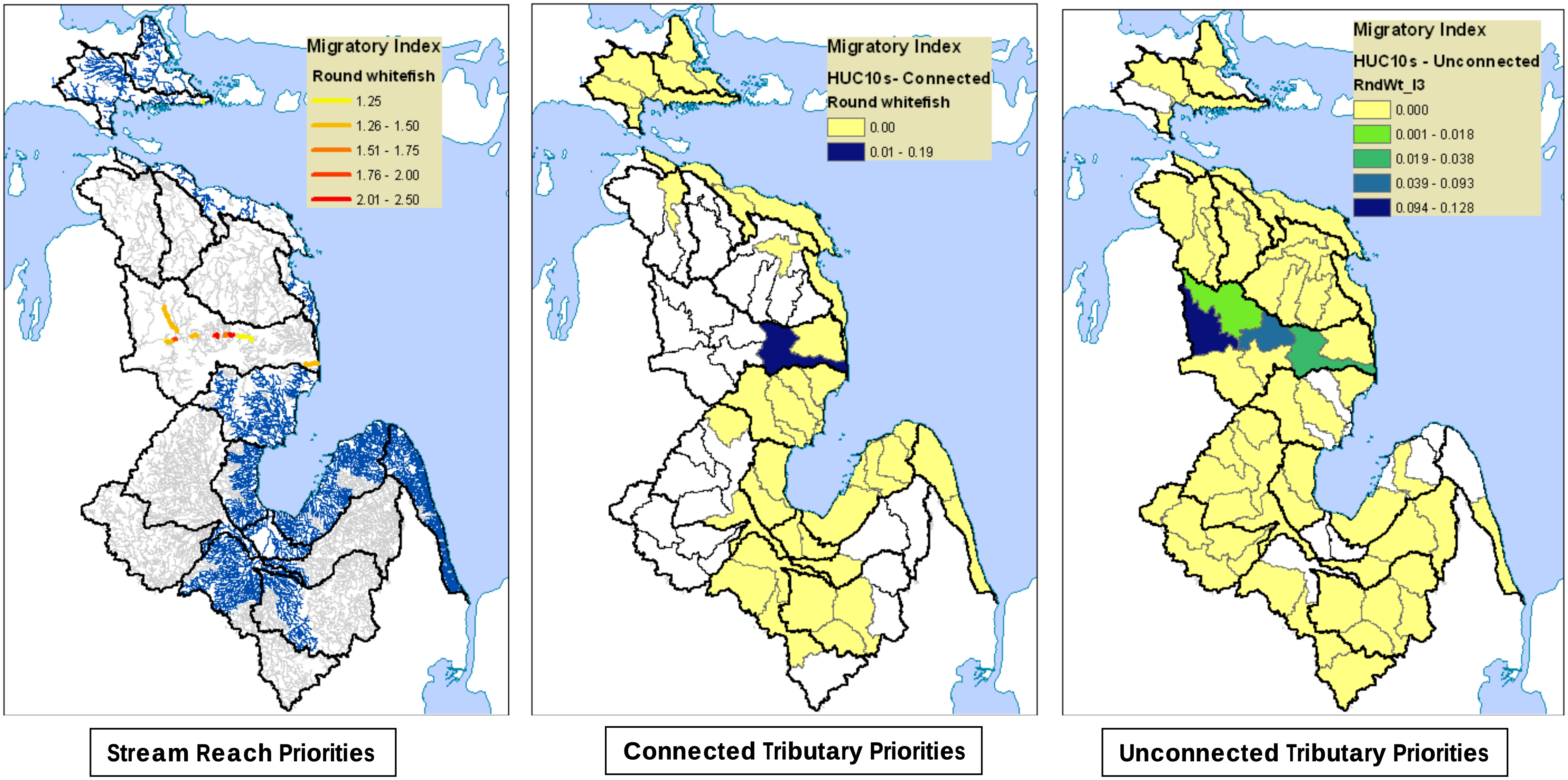
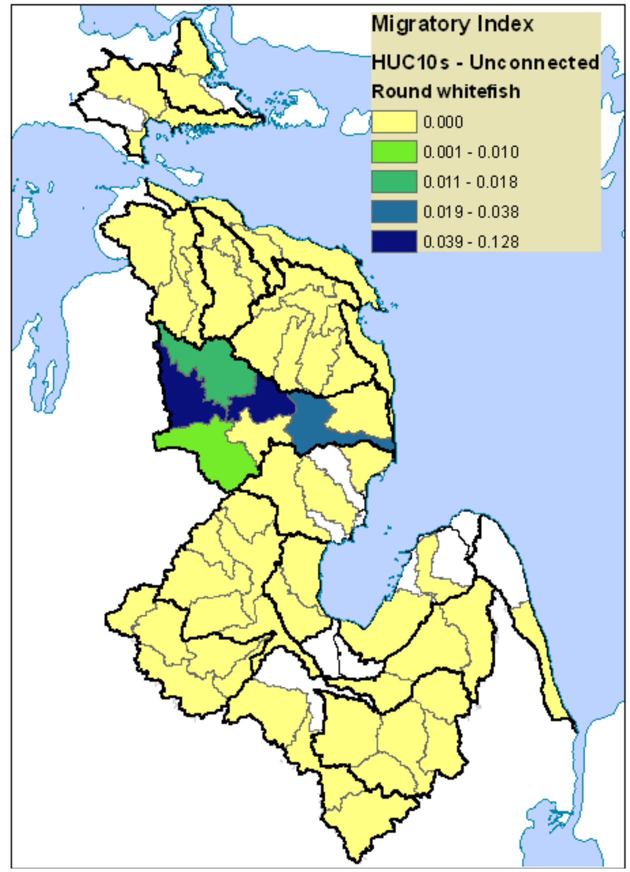


Figure 26. Tributaries important to Lake Huron round whitefish for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Round whitefish habitat was only identified in the Au Sable River watershed. Experts said that they had observed round whitefish in the South Branch of the Au Sable River as well, so this one modification was made manually to the unconnected watershed map (Figure 27). While round whitefish are extant in the Au Sable River, experts believe that with reconnection individuals from this population would migrate to and from Lake Huron.

Round Whitefish (*Prosopium cylindraceum*) - modified

Reaches Not Modified

Connected HUC10s Not Modified



Stream Reach Priorities

Connected Tributary Priorities

Unconnected Tributary Priorities

Figure 27. Tributaries important to Lake Huron round whitefish, with manual modification due to expert input, for (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Manual modifications were to reflect known occurrences of round whitefish in the South Branch of the Au Sable River. Unconnected habitat for Lake Huron round whitefish is only in the Au Sable River watershed.

Sauger (*Sander canadensis*)

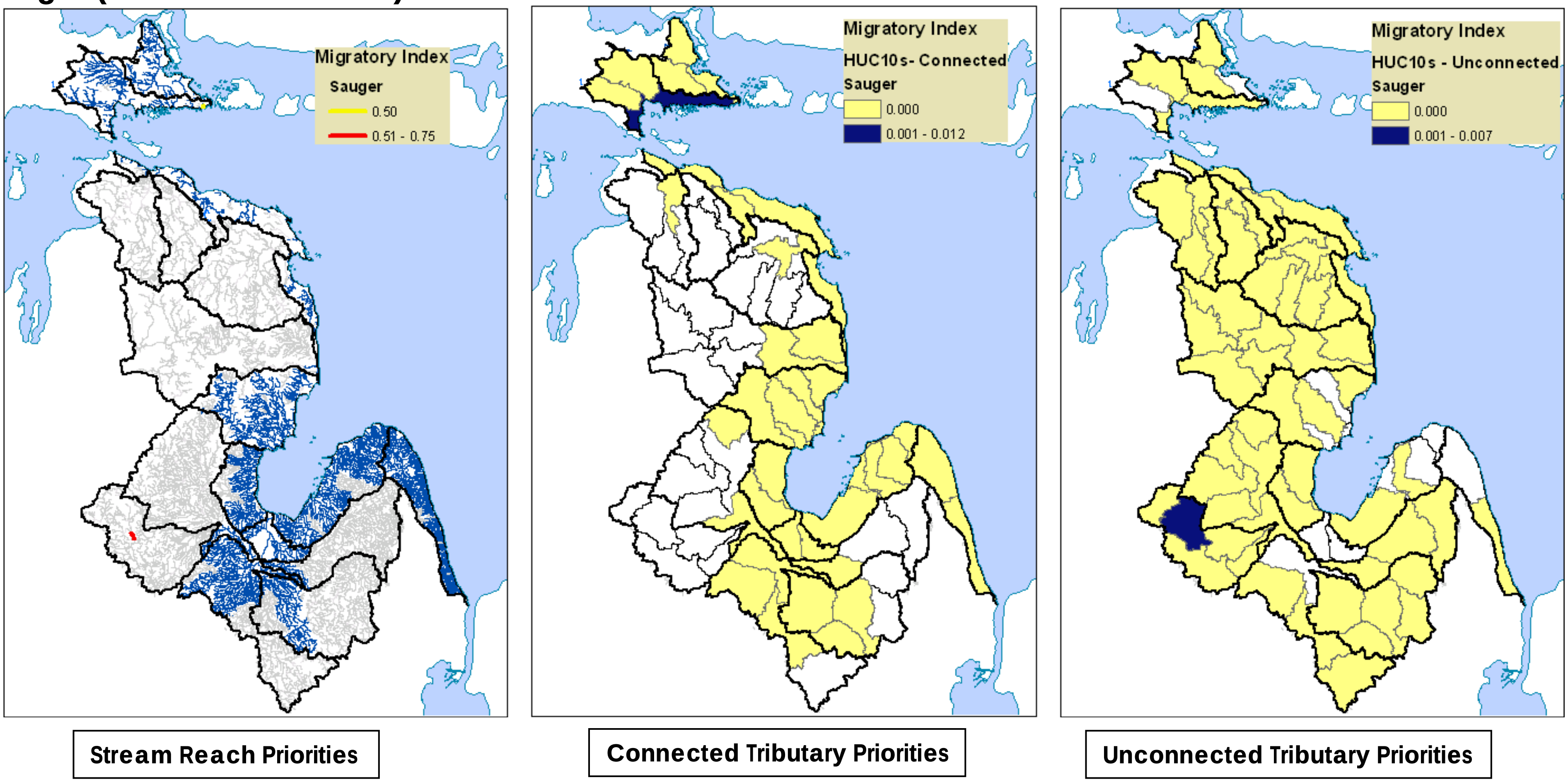
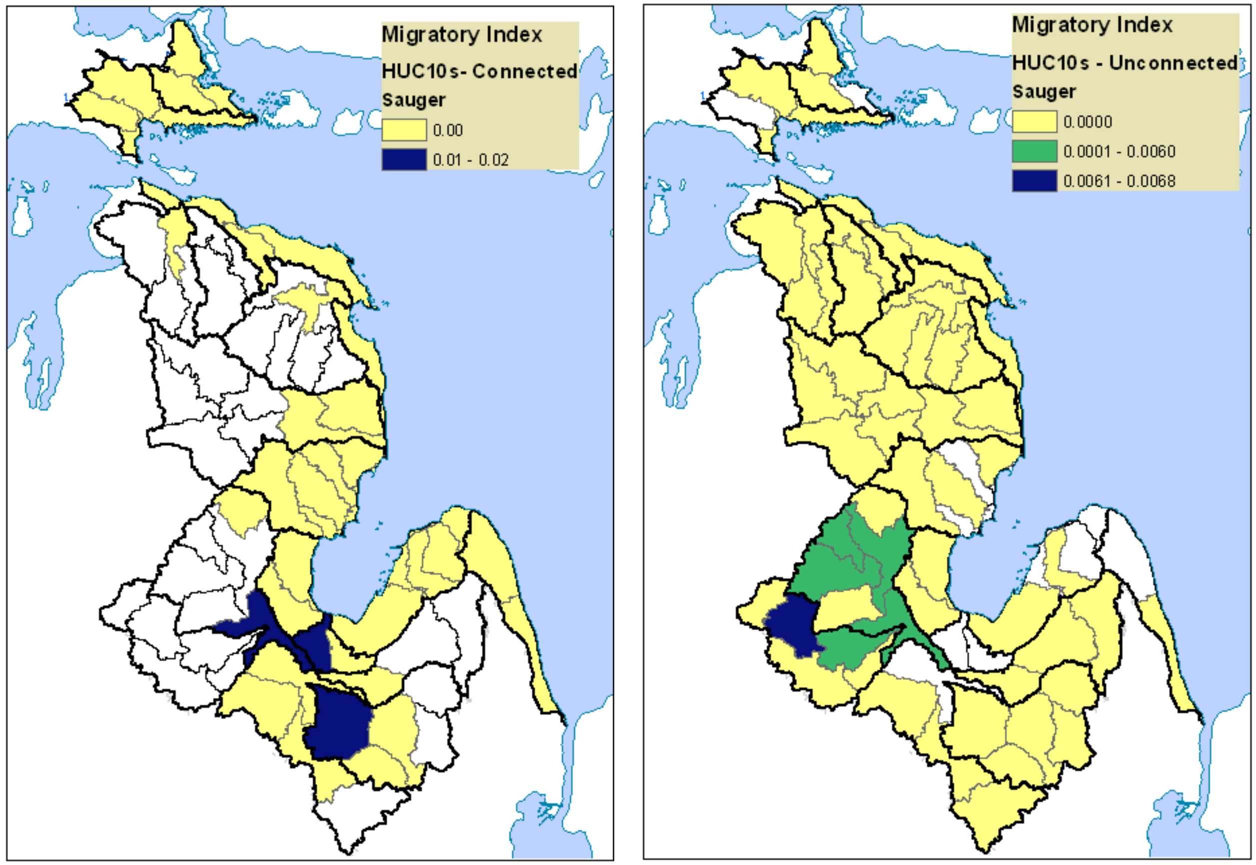


Figure 28. Tributaries important to Lake Huron sauger for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. There were only two stream location records in the data we assembled. Modifications were made for the sauger priority watersheds based on knowledge from participating experts (Figure 29).

Sauger (*Sander canadensis*) - modified

Reaches Not Modified



Stream Reach Priorities | **Connected Tributary Priorities** | **Unconnected Tributary Priorities**

Figure 29. Tributaries important to Lake Huron sauger, with manual modification due to expert input, for (B) watersheds based on connected streams and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Manual modifications were to reflect expert knowledge of historic accounts of sauger populations and available spawning habitat. The primary spawning habitat for sauger in Lake Huron historically was in the Saginaw River and its tributaries. The best potential (unconnected) sauger habitat is in the Tittabawassee River watershed.

Shorthead Redhorse (*Moxostoma macrolepidotum*) – With Gap

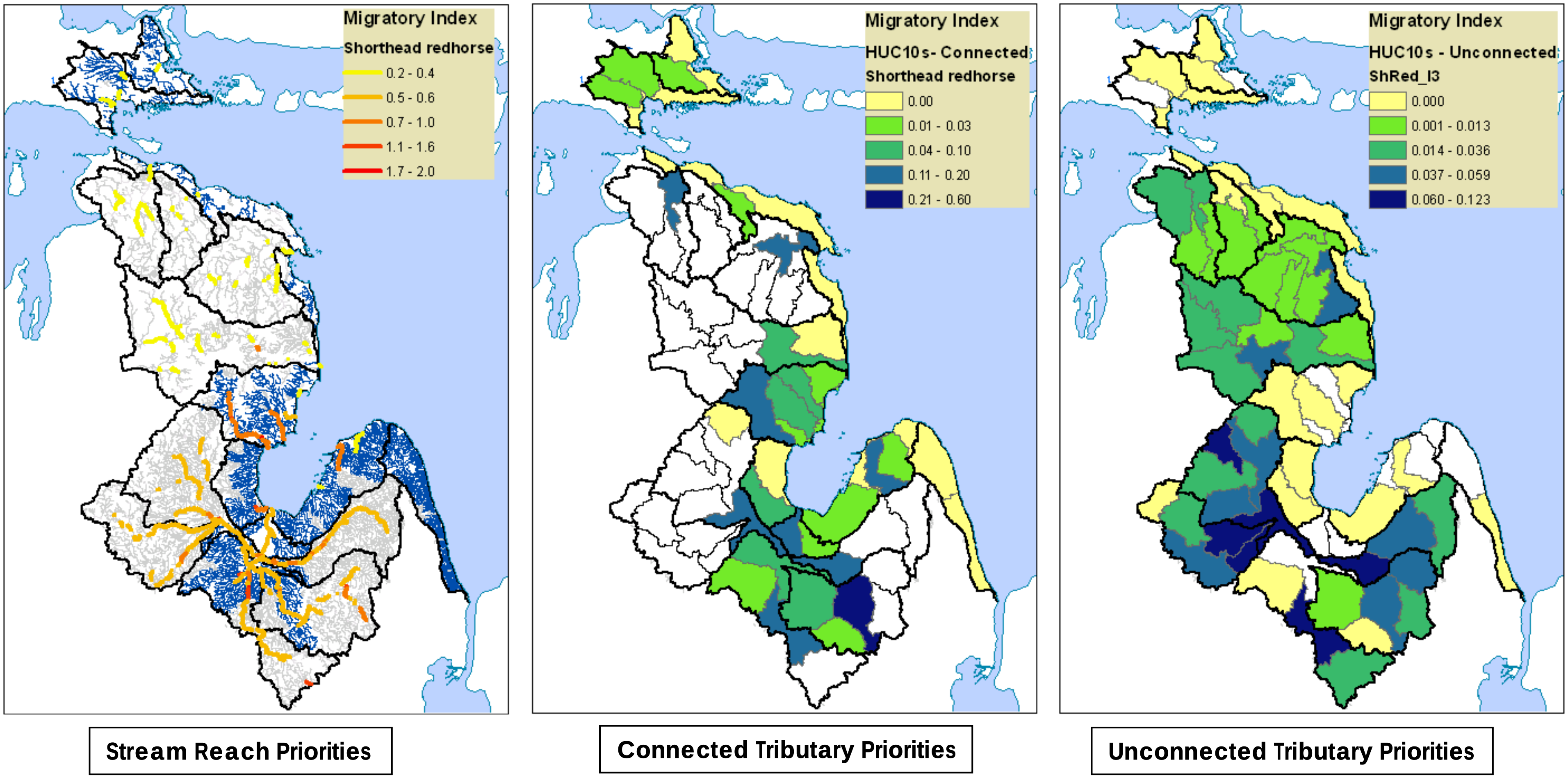
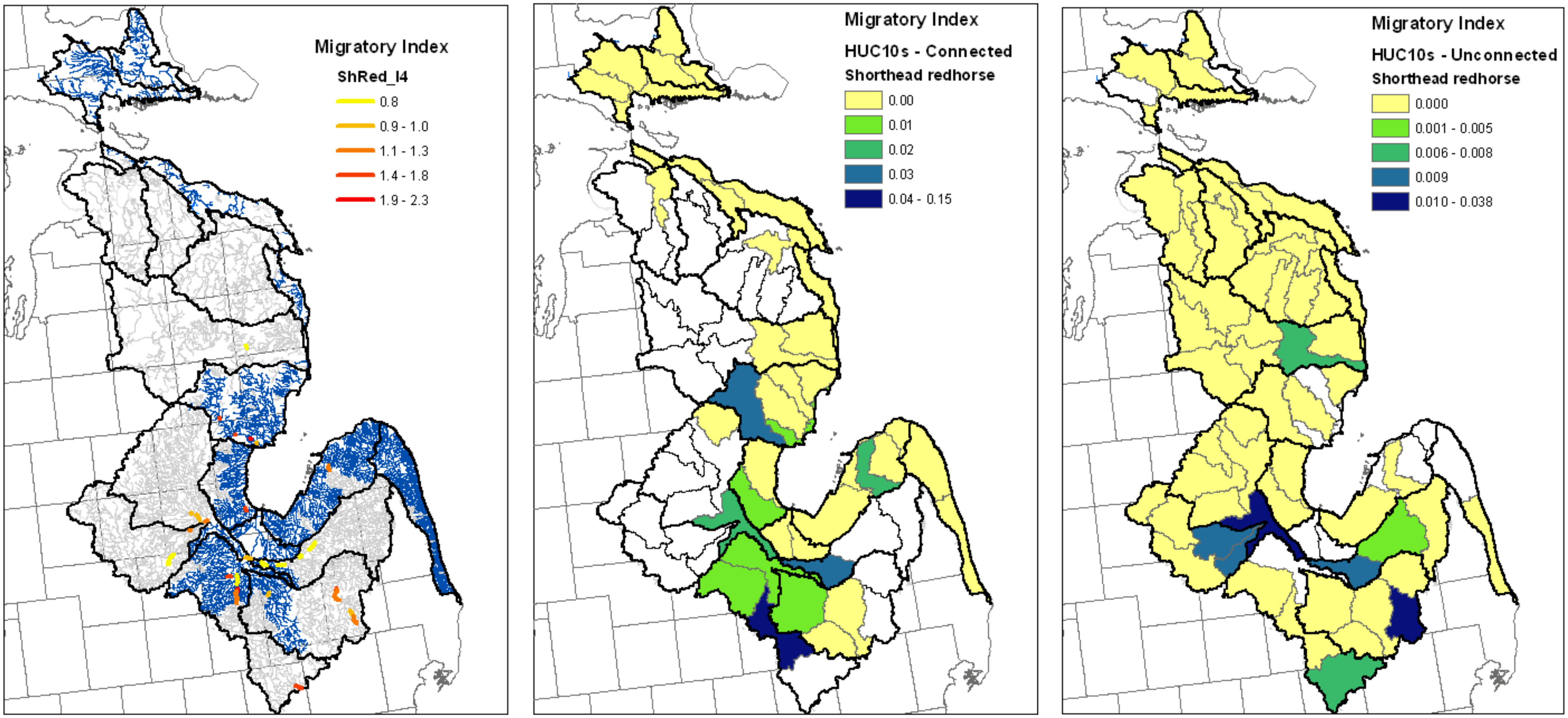


Figure 30. Tributaries important to Lake Huron shorthead redhorse for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Analyses indicated that shorthead redhorse are widely distributed. However, regional experts indicated that these distributions seemed to substantially overrepresent shorthead redhorse habitat, with whole watersheds included where they have never been documented. We reviewed the original data and found those areas were being driven by Aquatic Gap predicted areas. Given that shorthead redhorse are widely distributed throughout the region, including in Georgian Bay and northern Lake Huron, it seemed possible that the Aquatic Gap predicted areas may have been predicting historic habitat, but experts felt strongly that the habitat being predicted was not appropriate, so we recalculated the Index without Aquatic Gap (Figure 31).

Shorthead Redhorse (*Moxostoma macrolepidotum*) – Modified



Stream Reach Priorities | **Connected Tributary Priorities** | **Unconnected Tributary Priorities**

Figure 31. Tributaries important to Lake Huron shorthead redhorse, after modification by removing Aquatic Gap data from the analysis as recommended during expert review, for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Following removal of Aquatic Gap from the analysis, shorthead redhorse priority tributaries (connected and unconnected) are concentrated in Saginaw Bay, especially the Saginaw River watershed and the Rifle River.

Silver Redhorse (*Moxostoma anisurum*)

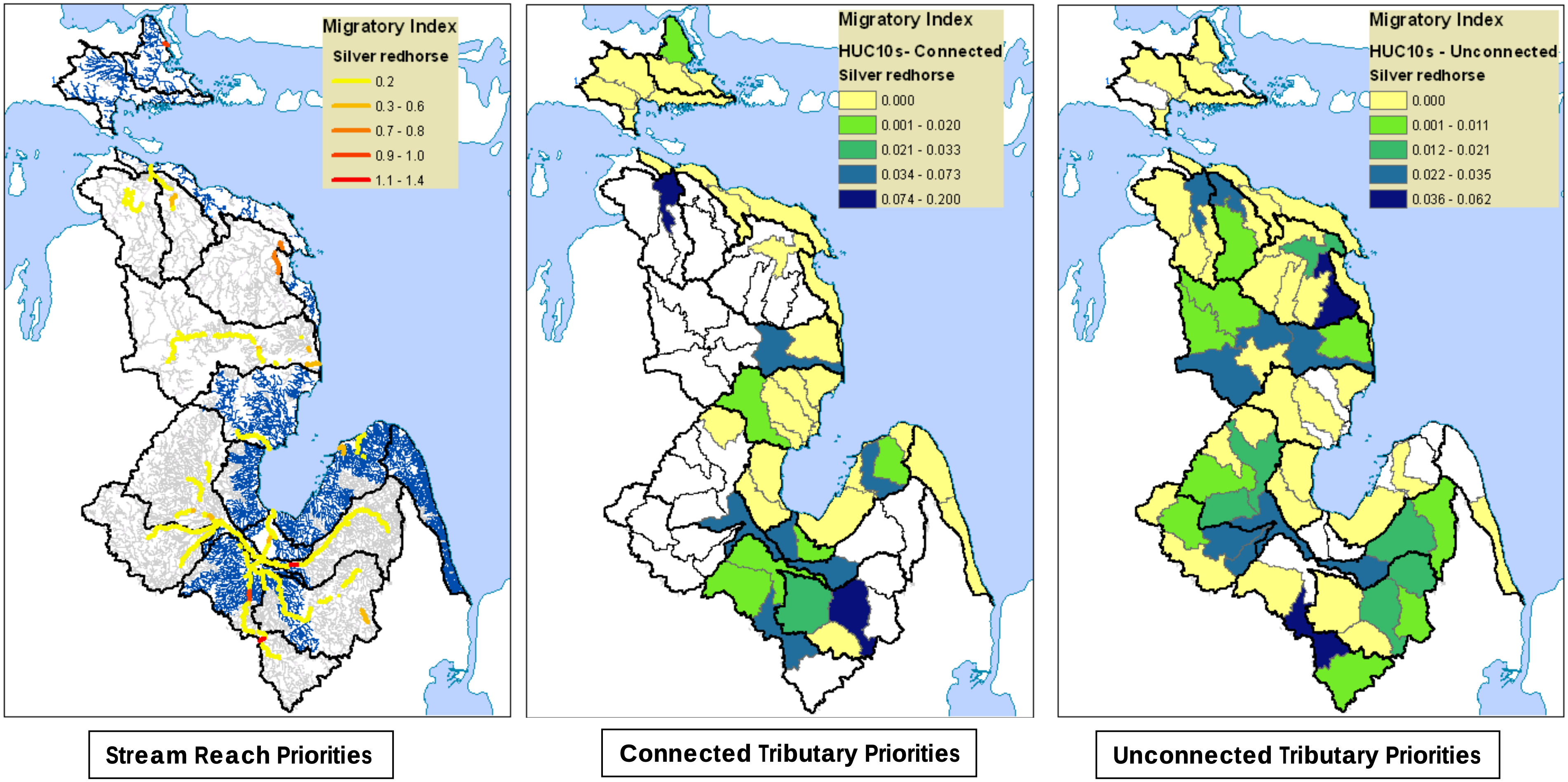
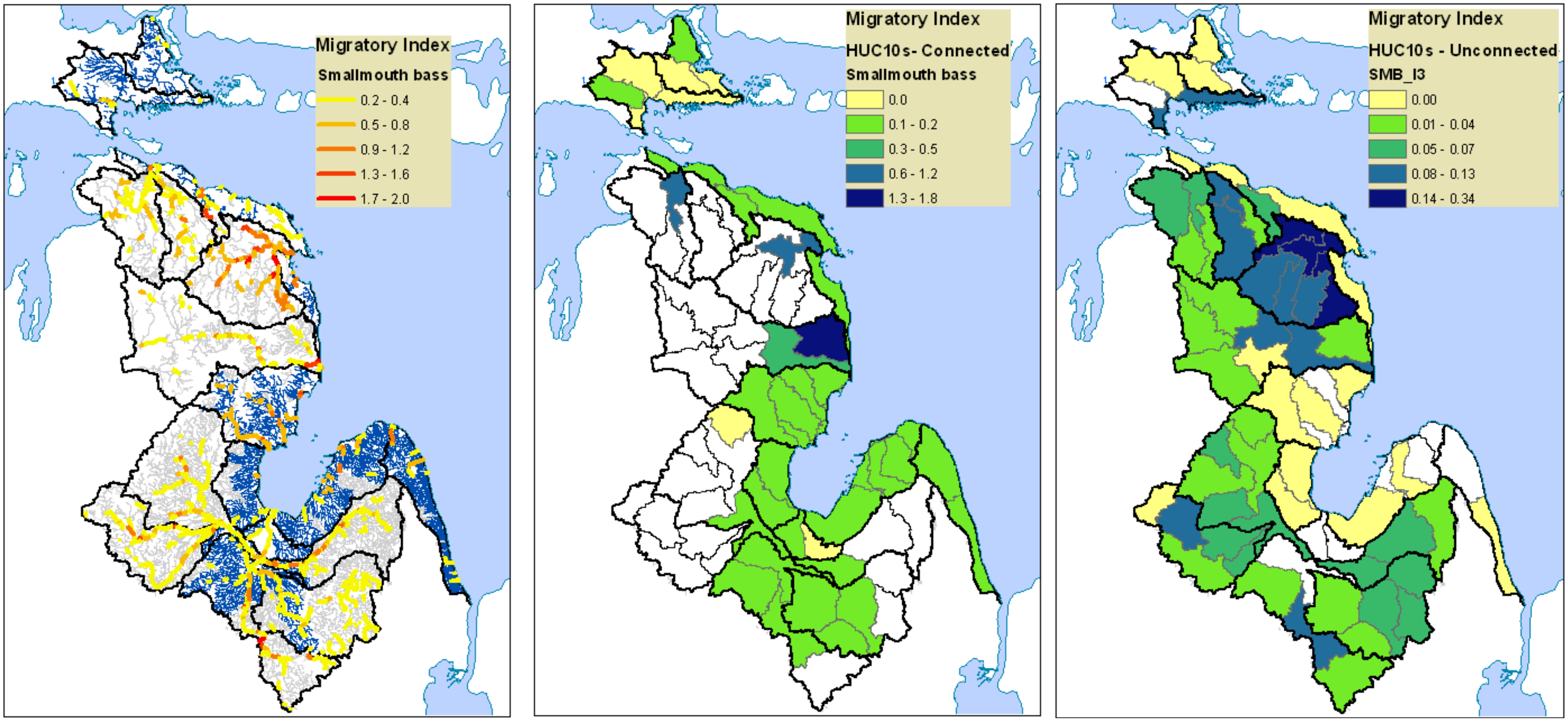


Figure 32. Tributaries important to Lake Huron silver redhorse for (A) specific stream locations, (B) watersheds based on streams connected to Lake Huron, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Silver redhorse habitat (connected and unconnected) is widely distributed along the larger tributary rivers of Lake Huron.

Smallmouth Bass (*Micropterus dolomieu*)



Stream Reach Priorities | **Connected Tributary Priorities** | **Unconnected Tributary Priorities**

Figure 33. Tributaries important to Lake Huron smallmouth bass for (A) specific stream locations, (B) watersheds based on streams connected to Lake Huron, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Smallmouth bass habitat is widely distributed, with the best potential (unconnected) habitat in the Thunder Bay River watershed.

Spottail Shiner (*Notropis hudsonius*)

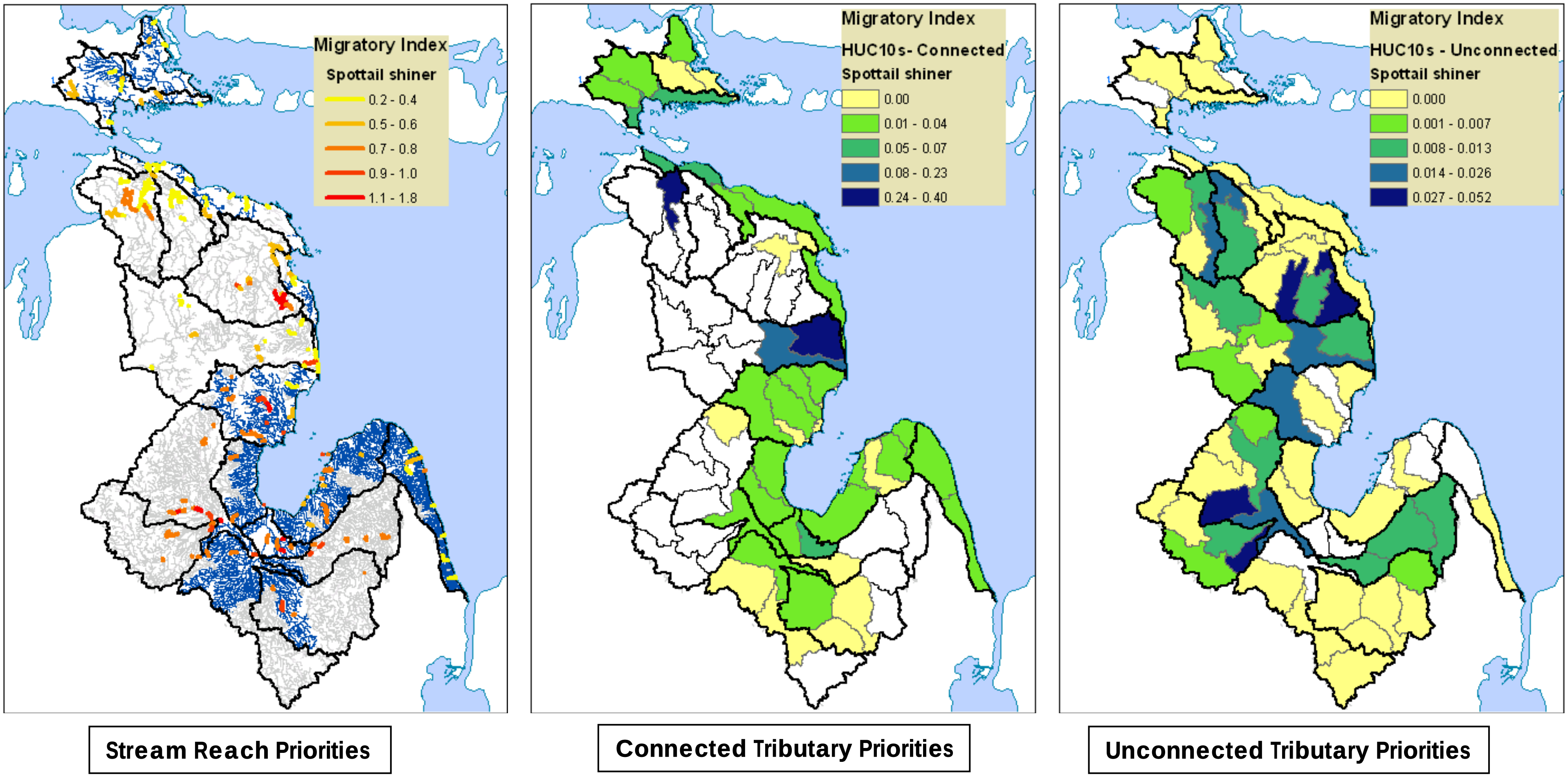
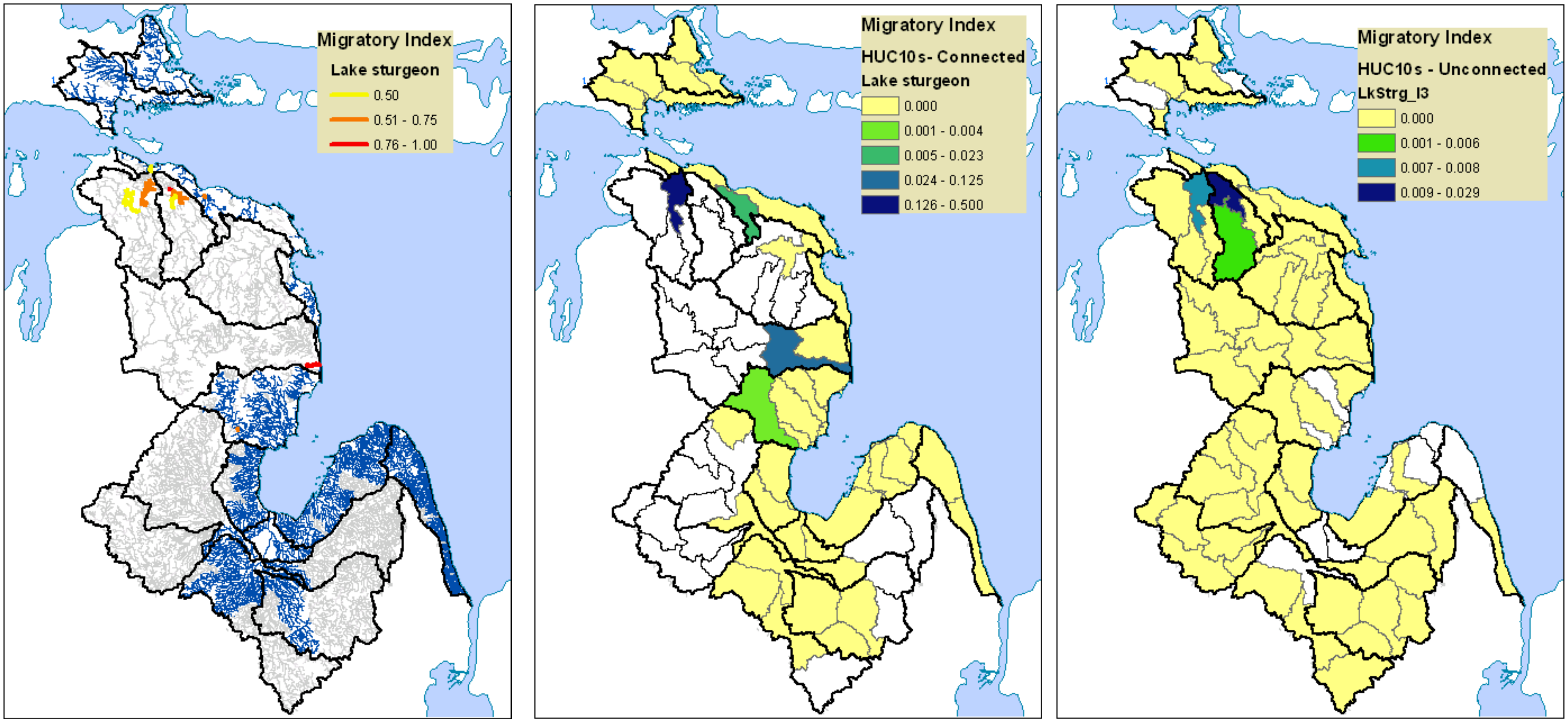


Figure 34. Tributaries important to Lake Huron spottail shiner for (A) specific stream locations, (B) watersheds based on streams connected to Lake Huron, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Spottail shiner habitat is widely distributed in Lake Huron. The best potential (unconnected) spottail shiner habitat is in the Tittabawassee and Thunder Bay River watersheds.

Lake Sturgeon (*Acipenser fulvescens*)

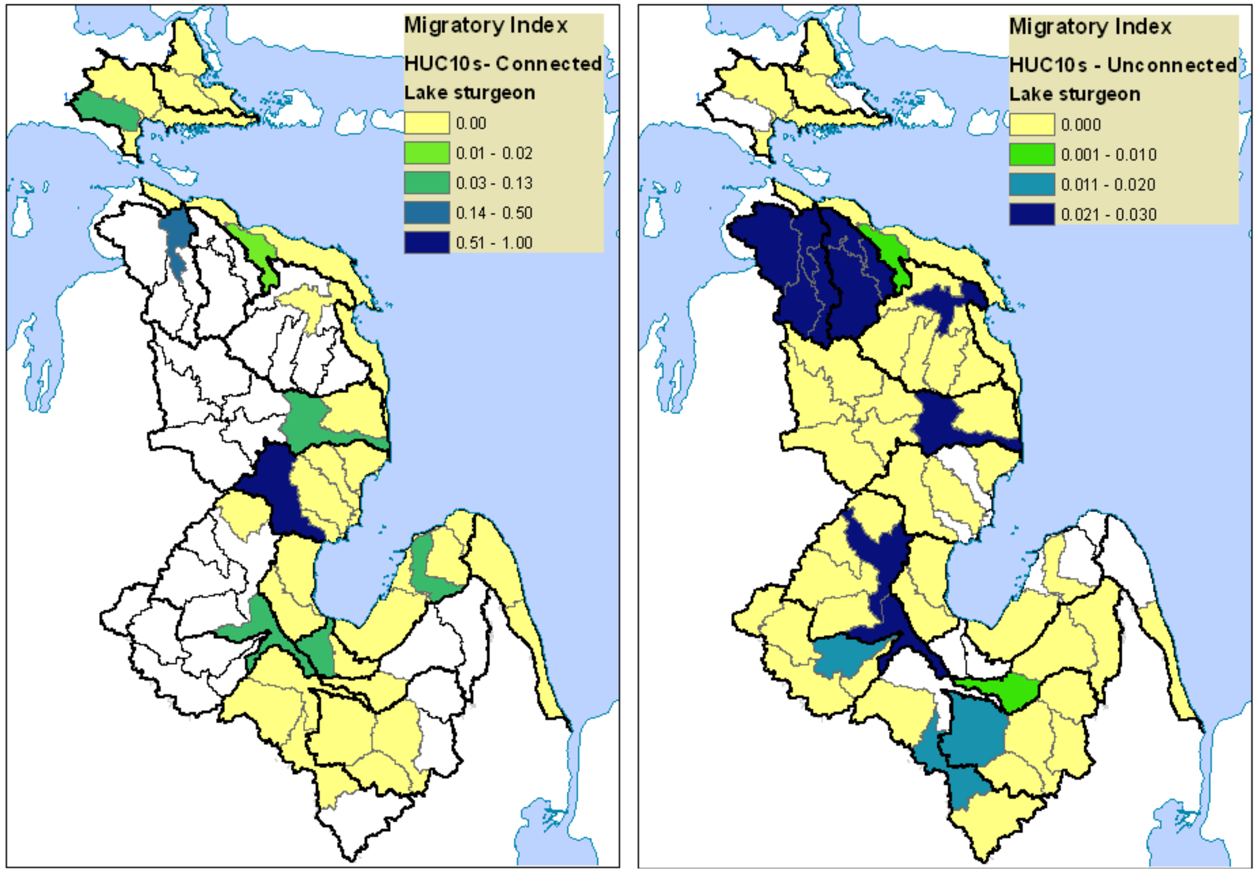


Stream Reach Priorities | **Connected Tributary Priorities** | **Unconnected Tributary Priorities**

Figure 35. Tributaries important to Lake Huron lake sturgeon for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Analyses found that Lake sturgeon habitat is found in several watersheds in Northern Lake Huron. However, experts pointed out that the survey data sources used in our analyses are not effective at sampling species like lake sturgeon and there are known lake sturgeon spawning areas that were not mapped. Therefore, modifications were made to the watershed maps, to reflect known migratory lake sturgeon spawning areas or habitat that would provide good spawning habitat, if connected (Figure 36).

Lake Sturgeon (*Acipenser fulvescens*) – modified (manually)

Reaches Not Modified



Stream Reach Priorities | **Connected Tributary Priorities** | **Unconnected Tributary Priorities**

Figure 36. Tributaries important to Lake Huron lake sturgeon, with manual modification due to expert input, for (B) watersheds based on connected streams and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Manual modifications reflect known recent or historic lake sturgeon spawning habitat. The best habitat currently available to sturgeon is in the Rifle River watershed. The best potential (unconnected) habitat is in the Tittabawassee, Au Sable, and Thunder Bay Rivers, as well as the Cheboygan River watershed where the extant, but isolated, Black River population occurs.

Trout-Perch (*Percopsis omiscomaycus*)

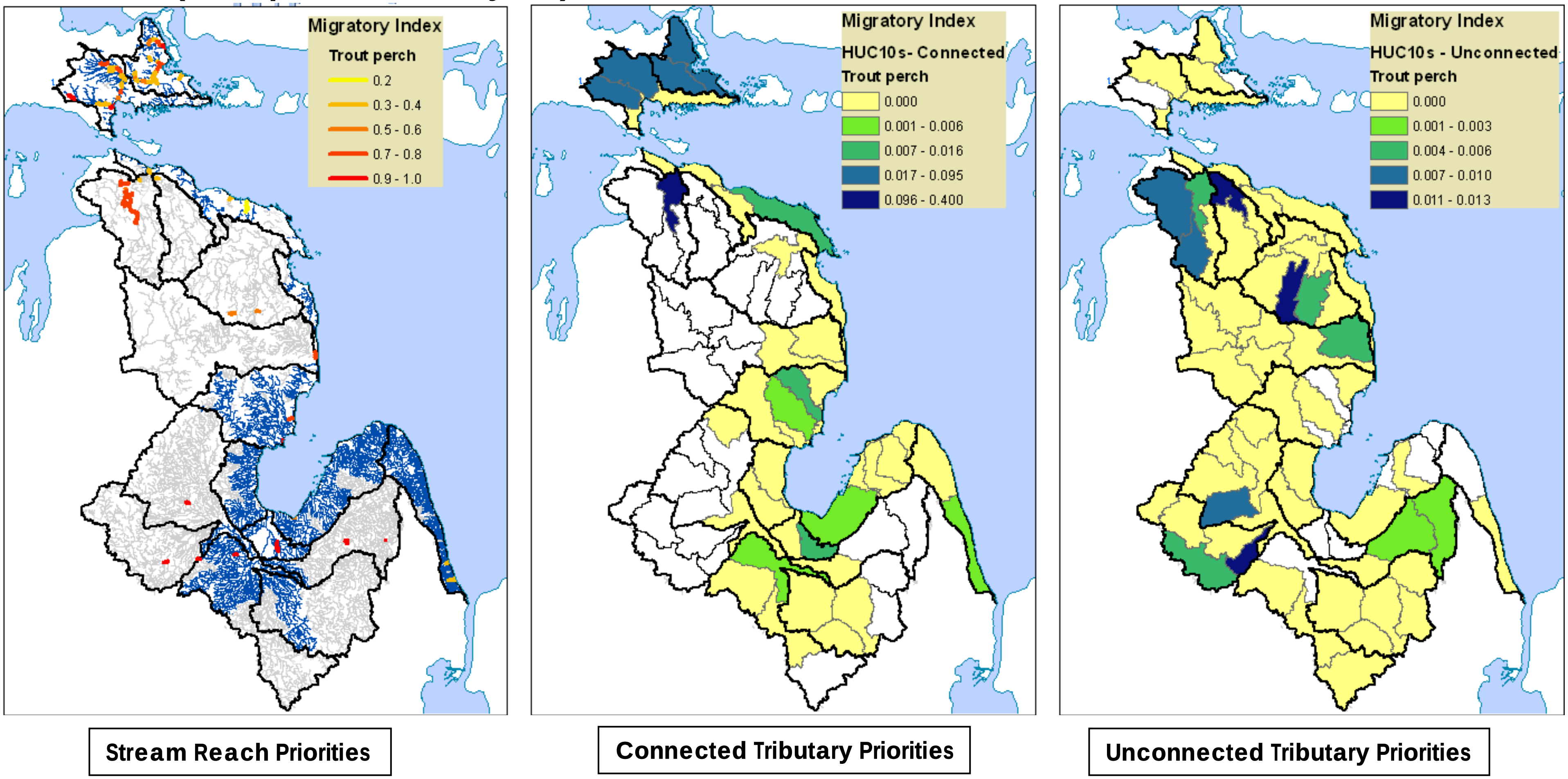
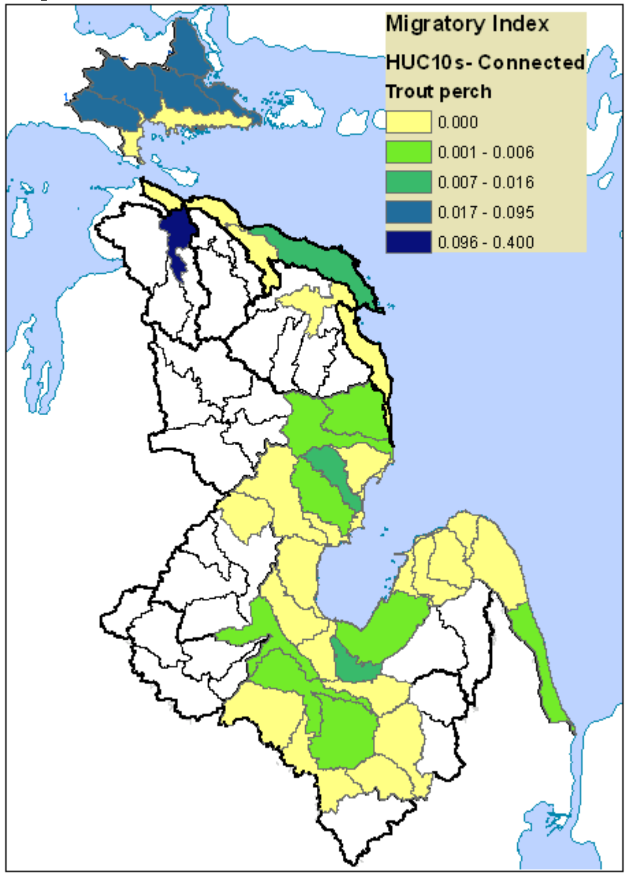


Figure 37. Tributaries important to Lake Huron trout-perch for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Trout-perch habitat is scattered through the Lake Huron watershed. Slight modifications were made to the connected tributary map, to reflect known current migratory trout-perch movement into the lower Tittabawassee and lower Flint Rivers to spawn (Figure 38). The best potential (unconnected) trout-perch habitat is in the Cheboygan River watershed.

Trout-Perch (*Percopsis omiscomaycus*) - modified

Reaches Not Modified



Unconnected HUC10s Not Modified

Stream Reach Priorities | **Connected Tributary Priorities** | **Unconnected Tributary Priorities**

Figure 38. Tributaries important to Lake Huron trout-perch, with manual modification due to expert input, for (B) watersheds based on connected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Manual modifications were to reflect known current migratory trout-perch movement into the lower Tittabawassee and lower Flint Rivers to spawn. Connected habitat for trout-perch is scattered through the Lake Huron watershed, but the highest priority habitat is in the UP and the lower Cheboygan River.

Walleye (*Sander vitreum*)

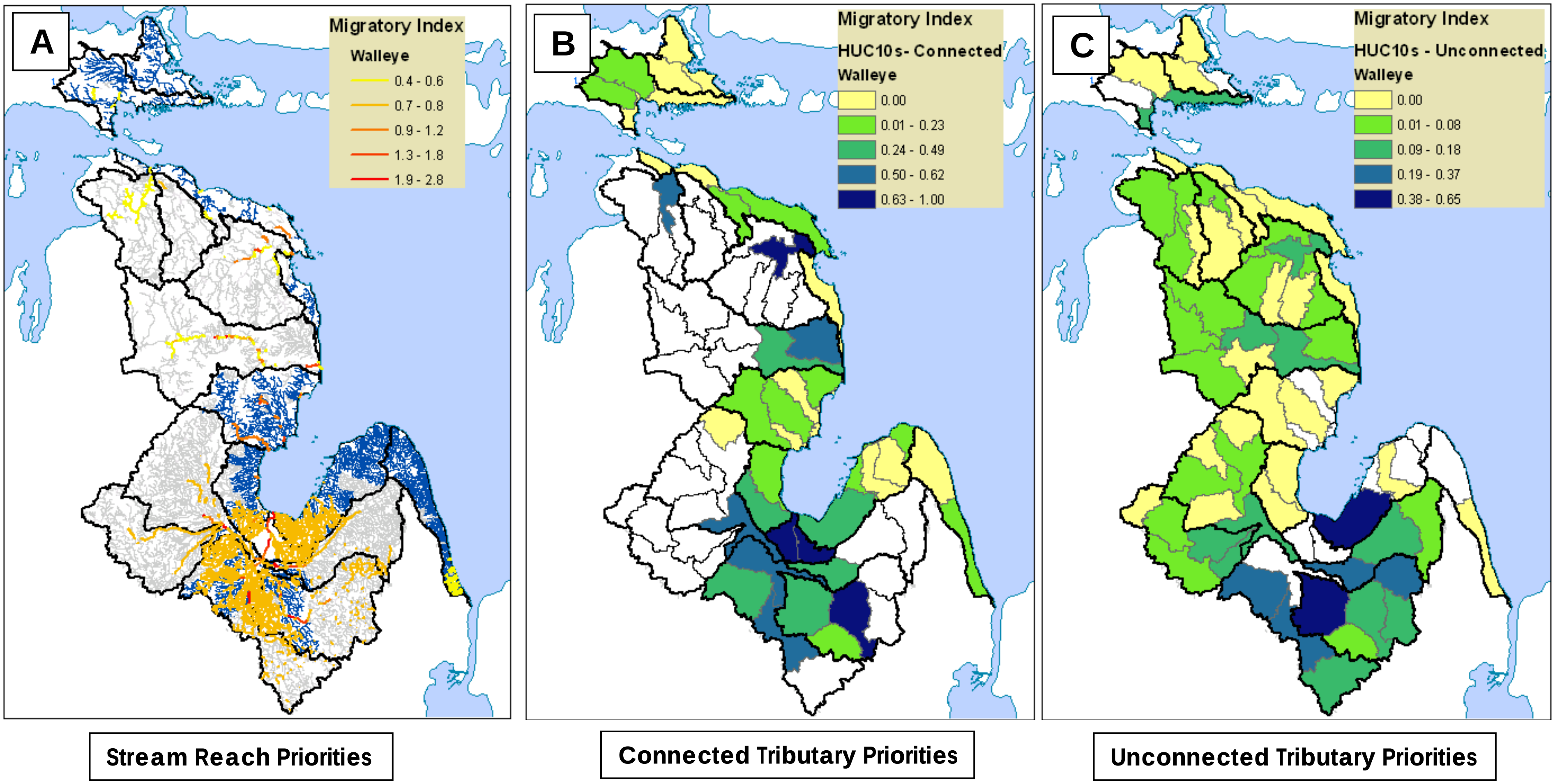


Figure 39. Stream reaches important to Lake Huron walleye for (A), specific stream locations (B), watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. These maps indicate that several connected tributaries in Saginaw Bay are important to walleye, including both connected and unconnected watersheds. In addition, the lower Thunder Bay River and Lower Cheboygan Rivers remain important to walleye, despite relatively little available habitat below the lowest dams. Important unconnected habitat includes the lower Flint River and lower Shiawassee River. Slight modifications were made to the tributary watershed maps to reflect known walleye habitat use or presence of walleye spawning habitat above lowest barriers (Figure 40).

Walleye (*Sander vitreum*) - modified

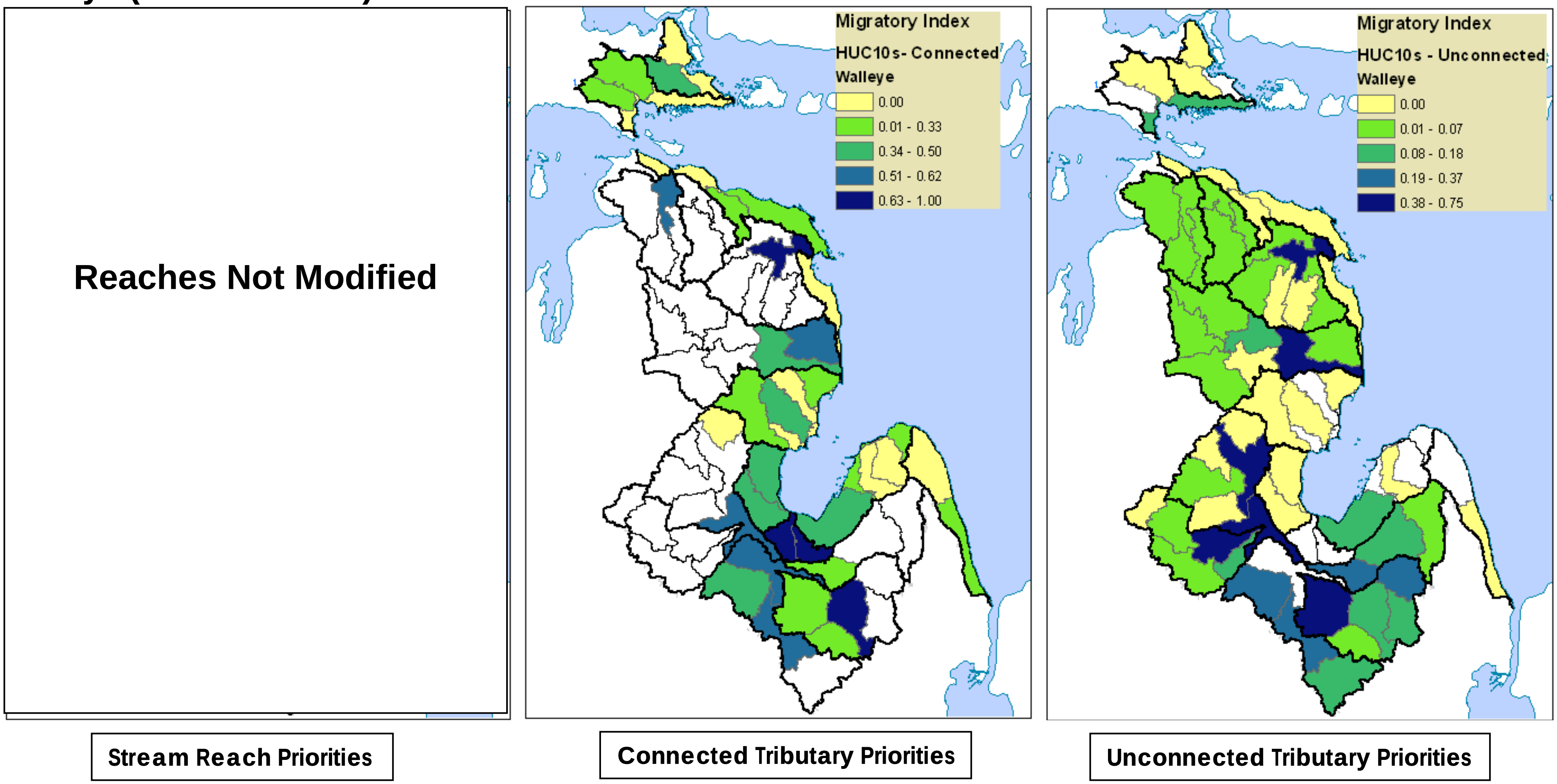


Figure 40. Tributaries important to Lake Huron walleye, with manual modification due to expert input, for (B) watersheds based on connected streams and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Manual modifications were to reflect known walleye habitat use or presence of walleye spawning habitat above lowest barriers. Walleye spawning habitat (connected and unconnected) is scattered throughout the Lake Huron basin, but the strongest areas include much of the Saginaw River watershed, the Au Sable River and the lower Thunder Bay River.

White Bass (*Morone chrysops*) – with Gap

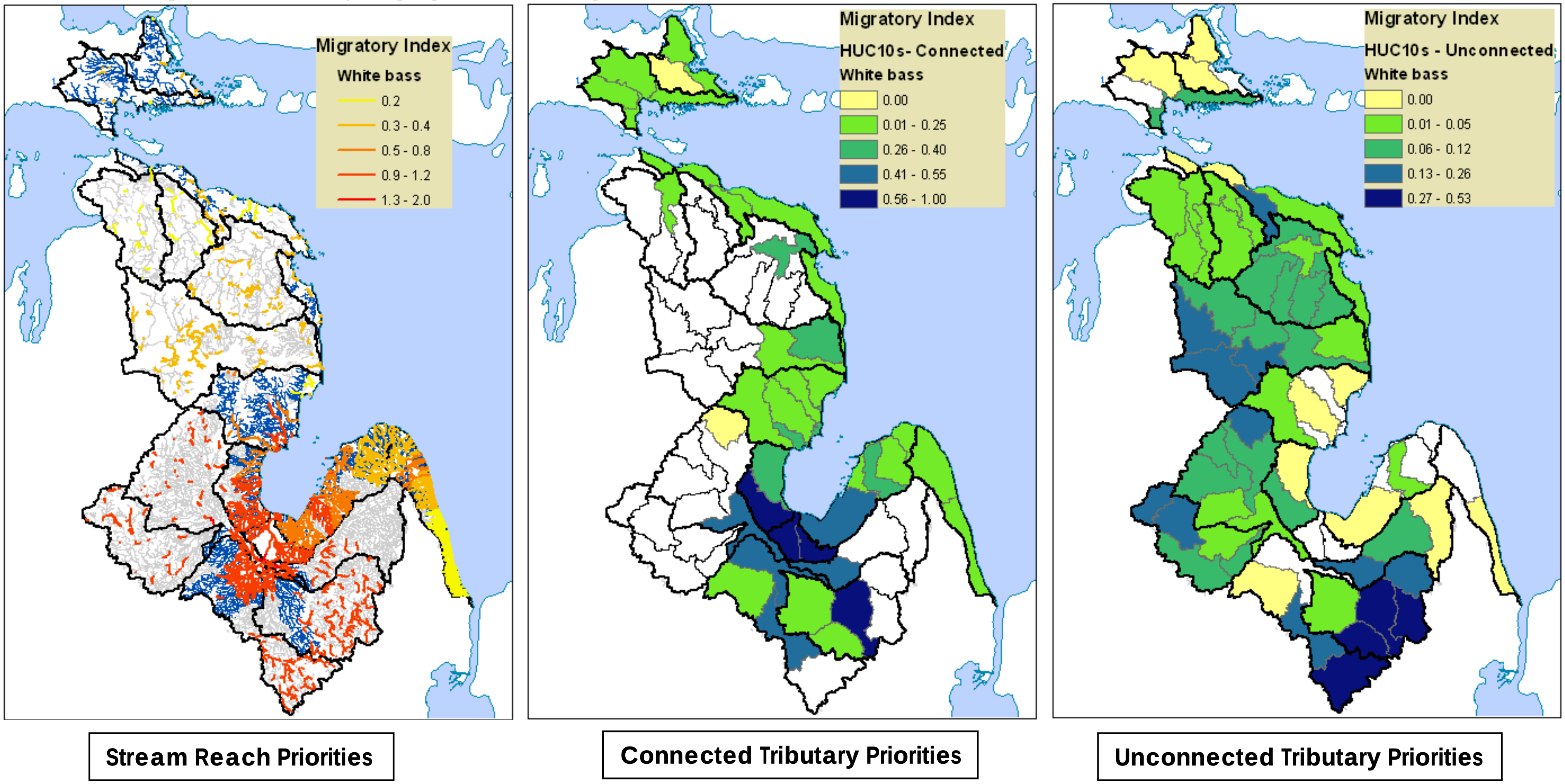


Figure 41. Tributaries important to Lake Huron white bass for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Analyses indicated that white bass are widely distributed throughout the Lake Huron basin. However, regional experts indicated that these distributions seemed to substantially overrepresent white bass habitat, with whole watersheds included where they have never been documented. We reviewed the original data and found those areas were being driven by Aquatic Gap predicted areas. Since experts felt strongly that much of the habitat being predicted was not appropriate, we recalculated the Index without aquatic Gap (Figure 42).

White Bass (*Morone chrysops*) – modified without Gap

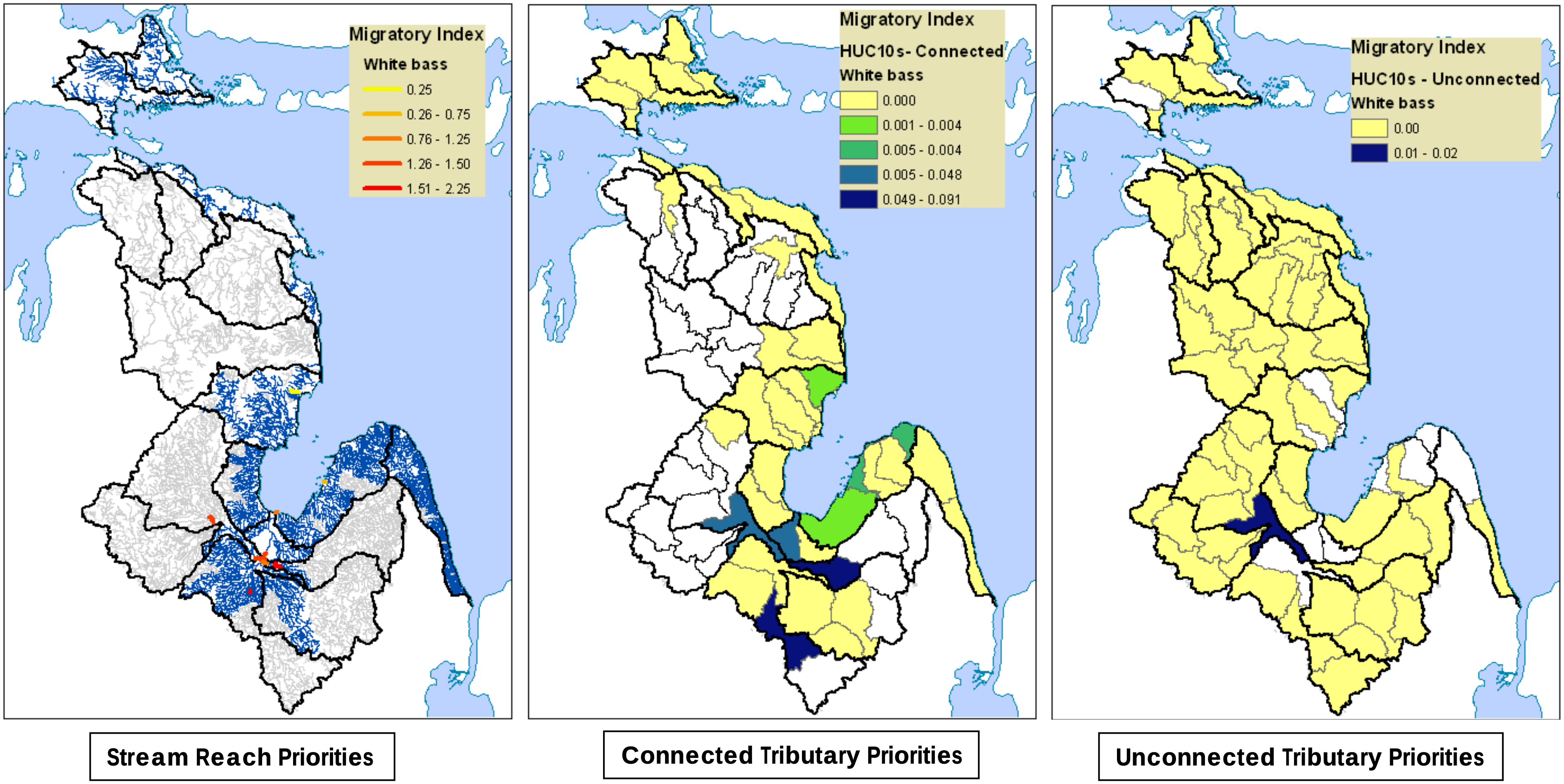


Figure 42. Tributaries important to Lake Huron white bass, after modification by removing Aquatic Gap data from the analysis as recommended during expert review, for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Following removal of Aquatic Gap from the analysis, white bass priority tributaries were centered within Saginaw Bay and concentrated in the Saginaw River system. The best connected white bass habitat is in the lower Shiawassee and Cass Rivers and the best potential (unconnected) habitat is in the Tittabawassee River.

White Sucker (*Catostomus commersonii*)

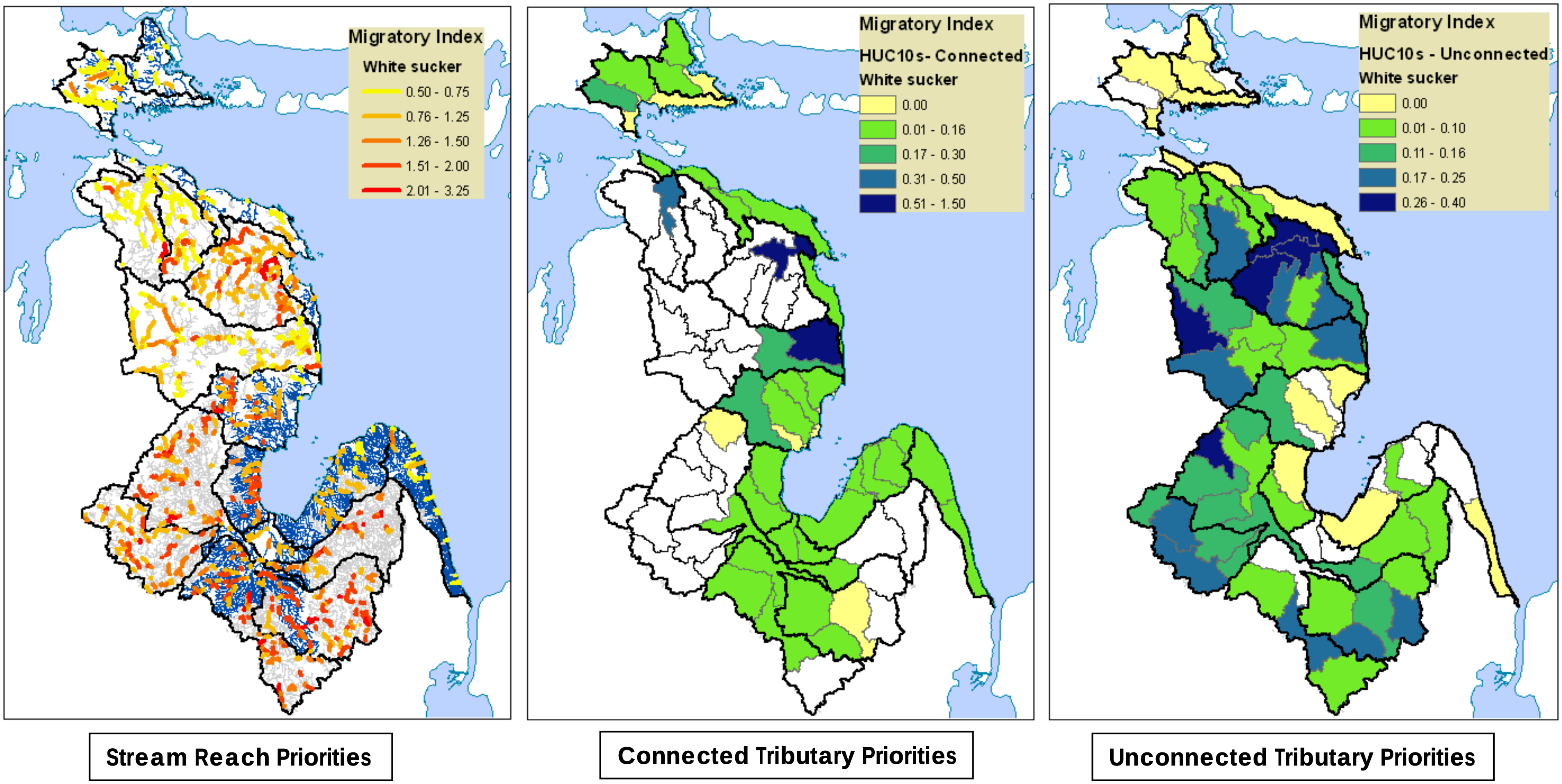
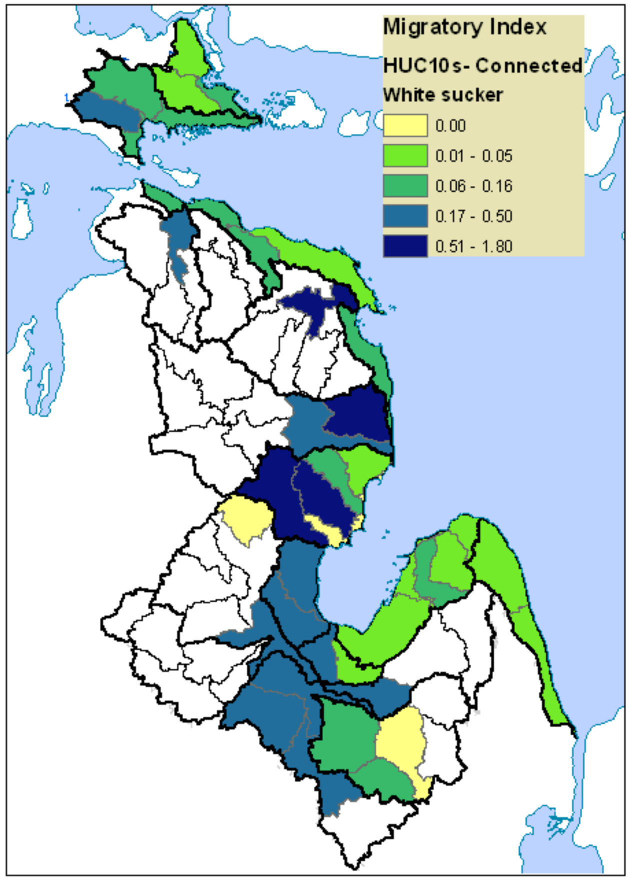


Figure 43. Stream reaches important to Lake Huron white sucker for (A), specific stream locations (B), watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Modifications were made to the connected tributary watershed map to reflect known white sucker habitat use or presence of white sucker spawning habitat (Figure 44). The best potential (unconnected) white sucker habitat is in the Thunder Bay River watershed.

White Sucker (*Catostomus commersonii*) - modified

Reaches Not Modified



Unconnected HUC10s Not Modified

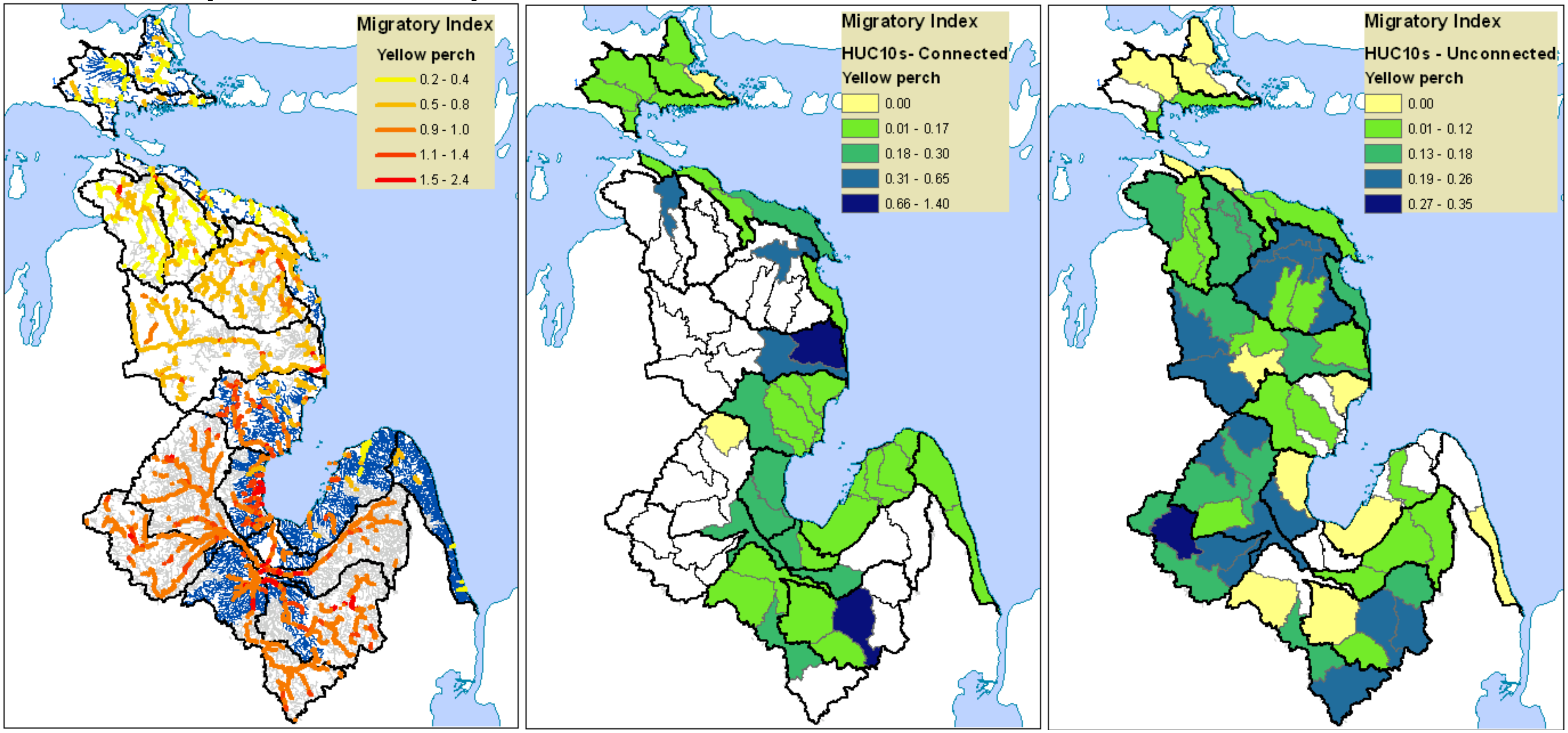
Stream Reach Priorities

Connected Tributary Priorities

Unconnected Tributary Priorities

Figure 44. Tributaries important to Lake Huron white sucker, with manual modification due to expert input, for (B) watersheds based on connected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Manual modifications were to reflect known white sucker habitat use or presence of white sucker spawning habitat. White sucker spawning habitat is scattered throughout the Lake Huron basin, but the most important connected tributaries are the Rifle River, East Branch of the Au Gres River, the Pine River branch of the Au Sable, and the lower Thunder Bay River. The Saginaw River system also contains substantial habitat important to white suckers.

Yellow Perch (*Perca flavescens*)



Stream Reach Priorities | **Connected Tributary Priorities** | **Unconnected Tributary Priorities**

Figure 45. Stream reaches important to Lake Huron yellow perch for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Yellow perch habitat is broadly distributed within the Lake Huron basin, including both connected and unconnected tributaries. However, regional experts indicated that these distributions seemed to overrepresent yellow perch habitat, particularly in inland watersheds not close to Lake Huron. We reviewed the original data and found that Aquatic Gap predicted areas contributed to this pattern. Since experts felt strongly that much of the habitat being predicted was not appropriate, we recalculated the Index without Aquatic Gap. In addition, some watersheds values were modified based on expert input. (Figure 46).

Yellow Perch (*Perca flavescens*) – modified

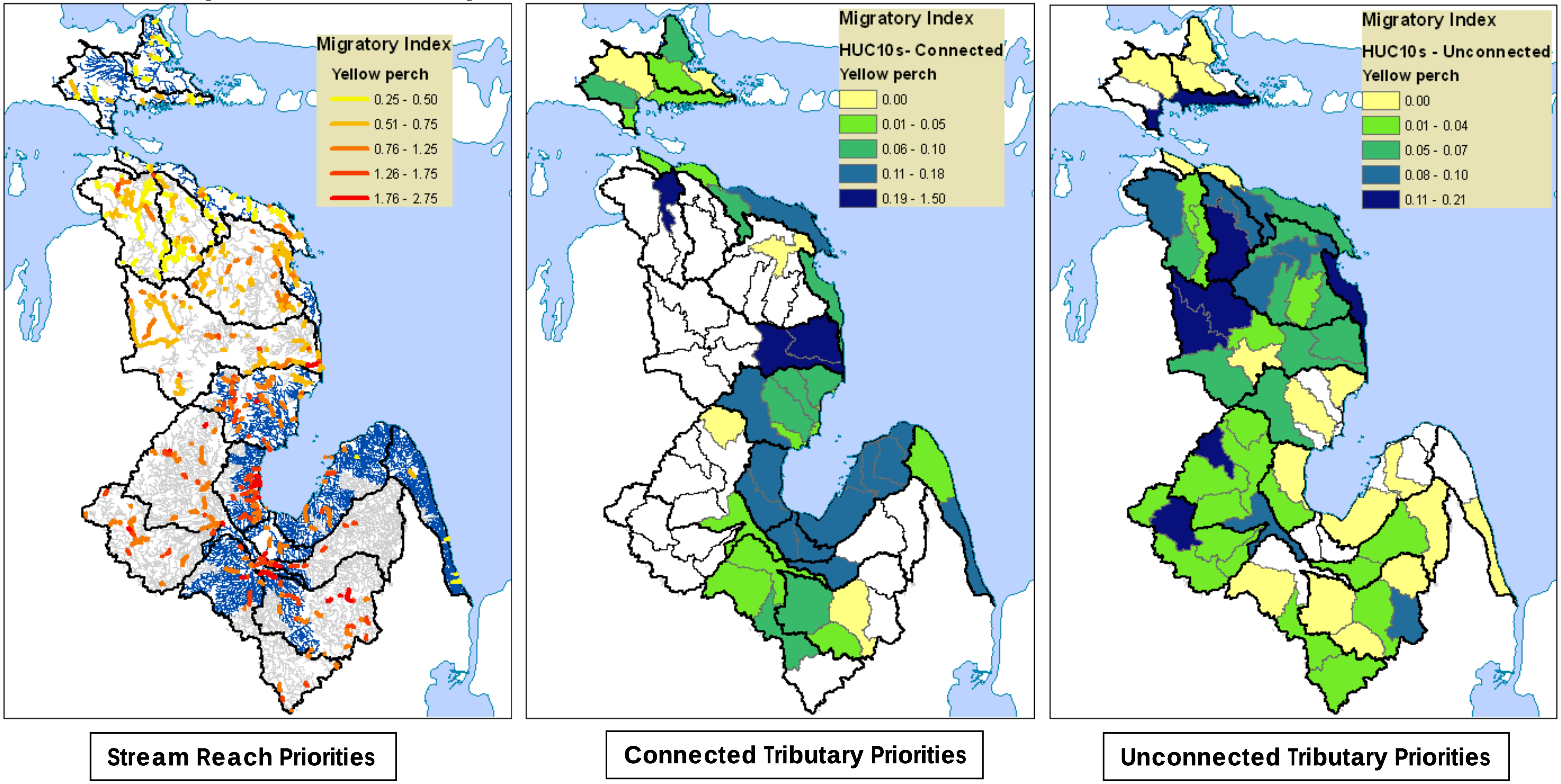


Figure 46. Tributaries important to Lake Huron yellow perch, after modification by removing Aquatic Gap data from the analysis--as recommended during expert review, for (A) specific stream locations, (B) watersheds based on connected streams, and (C) watersheds based on unconnected streams. Watersheds in white either have no connected streams on the connected maps or no unconnected streams on the unconnected maps. Yellow perch habitat is widely distributed in Lake Huron. The scores are similar to the original analysis, but include higher priorities for Saginaw Bay coastal tributaries.