

## Appendix 9.3: Green Bay Open Water West

Written by Erin Giese and Dr. James Horn

<b>Location</b> (centroid)	Lat. 44.583458°, Lon. -88.002331° <sup>1</sup> (NAD 1983, UTM Zone 16N)																					
<b>Total Area</b> (ha)	2,165.46 ha																					
<b>Area Public Land</b> (ha)	The boundaries of the Green Bay Open Water West priority area are located within the coastal zone/waters of the bay of Green Bay and are thus entirely publicly owned. Depending on lake levels, parts of the west shore (e.g., Peters Marsh) may overlap with the boundaries of the Green Bay Open Water West priority area.																					
<b>Area of Habitat Types Present (ha) and Percent of Each Habitat Type</b>	<p>Dominant Habitat Types: These habitat types were documented during a July 2015 habitat mapping effort led by the University of Wisconsin-Green Bay Cofrin Center for Biodiversity (CCB) across the Lower Green Bay and Fox River Area of Concern (LGB&amp;FR AOC)<sup>2</sup>. Habitat types within Green Bay Open Water West are displayed as a static map at the bottom of this document. Note that the extent of submergent marsh was refined by the CCB's 2017 submerged aquatic vegetation field surveys. There is a total of 2,165.44 ha of natural habitat in Green Bay Open Water West.</p> <table border="1"> <thead> <tr> <th>Habitat Type</th> <th>Area (ha)</th> <th>Percent</th> </tr> </thead> <tbody> <tr> <td>Emergent Marsh (High Energy Coastal)</td> <td>7.68</td> <td>0.35</td> </tr> <tr> <td>Great Lakes Beach</td> <td>4.52</td> <td>0.21</td> </tr> <tr> <td>Green Bay Open Water</td> <td>2100.11</td> <td>96.98</td> </tr> <tr> <td>Hardwood Swamp</td> <td>0.15</td> <td>0.01</td> </tr> <tr> <td>Submergent Marsh</td> <td>51.60</td> <td>2.38</td> </tr> <tr> <td>Tributary Open Water</td> <td>1.38</td> <td>0.06</td> </tr> </tbody> </table> <p><i>Disclaimer!</i> Because this priority area is located within the Great Lakes coastal zone, the amount of habitat types can vary drastically across years and even within years (or months) due to changing Great Lakes water levels, precipitation, and seiche. Within this priority area specifically, the amounts of emergent and submergent marsh and Great Lakes beach are known to fluctuate significantly from year to year and within years. The habitat types listed above and mapped below are based on a field effort conducted in July 2015. Plants recorded in the "Natural Habitat Communities and Significant Plants" section were primarily documented in July 2015 and late summer/fall 2016 and 2017. Great Lakes water levels were much higher in 2016 and 2017 than in July 2015.</p>	Habitat Type	Area (ha)	Percent	Emergent Marsh (High Energy Coastal)	7.68	0.35	Great Lakes Beach	4.52	0.21	Green Bay Open Water	2100.11	96.98	Hardwood Swamp	0.15	0.01	Submergent Marsh	51.60	2.38	Tributary Open Water	1.38	0.06
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<b>General Description</b>	The Green Bay Open Water West priority area consists of the western half of the open water/pelagic zone of the lower bay of Green Bay, which is the western arm of Lake Michigan. It is somewhat arbitrarily distinguished and separated from the Green Bay Open Water East priority area by the shipping channel, though there are some distinct differences between the eastern and western halves of the bay. Shallower areas in the Duck Creek Delta, along the southern shoreline of Longtail Point, in Dead Horse Bay, and behind the Cat Island Wave Barrier can range from 0.30 m to 1.52 m (1-5 ft) in depth <sup>3</sup> . Deeper waters occur in between Longtail Point and the Cat Island Wave Barrier with depths up to 3.35-4.88 m (11-16 ft) and in the shipping channel, which can be up to 7.32-7.92 m (24-26 ft) deep <sup>3</sup> . The Fox River empties into the lower bay, and the water currents move in a counterclockwise direction starting by traveling up the eastern shore to Sturgeon Bay, at which point the currents turn west <sup>4</sup> . Sediments largely consist of sand and silt <sup>38</sup> . Unfortunately, water quality in the lower bay has been poor																					

<sup>1</sup> File "AOC\_PriorityAreas.v09\_20171212.shp"

<sup>2</sup> LGB&FR AOC 2015 habitat field mapping effort

<sup>3</sup> U.S. Army Corps of Engineers Map of the Head of Green Bay, including Fox River below De Pere, Wisconsin, Chart No. 725 from August 1966

<sup>4</sup> Klump et al. 1997: Sedimentary phosphorus cycling and a phosphorus mass balance for the Green Bay, Lake Michigan ecosystem

	<p>for decades. The LGB&amp;FR AOC was originally listed as a Great Lakes Area of Concern in 1988 due to poor water quality, contaminated sediments, and degraded or lost habitat. Waters within the LGB&amp;FR AOC regularly report high concentrations of total phosphorus, total suspended solids, nitrates/nitrites, and toxic chemicals, leading to poor overall water quality<sup>5,46</sup>. It can also be turbid and experience summer and late fall blooms of harmful algae<sup>5</sup>.</p> <p>Despite water quality issues, a great number of fish and wildlife still use the lower bay's pelagic zone. The Green Bay Open Water West (and East) priority area is extremely well studied and may in fact be one of the most studied priority areas in the LGB&amp;FR AOC. Over the past several decades, scientists from agencies, non-profit organizations, universities, Oneida Tribe, and other organizations have conducted dozens of research projects and collected data on fish, water quality, invertebrates, birds, and plants. Like other Great Lakes, large ships and freighters regularly use the pelagic zone of the bay of Green Bay via the shipping channel for importing and exporting products and goods. Residents and visitors of Green Bay regularly use the waters of the lower bay for fishing, hunting, boating, swimming, diving, water sports, and nature viewing. Therefore, improving the quality of lower Green Bay waters and associated habitats would improve the livelihood and economics of both wildlife and people.</p>
<b>Special Features</b>	<ul style="list-style-type: none"> <li>• Provides critical open water and nearshore fish habitat.</li> <li>• Provides habitat for open water and nearshore aquatic invertebrates, including freshwater mussels, aquatic insects, arthropods, annelids, etc.</li> <li>• Contains Great Lakes beach, which is rare to both the state of WI and the LGB&amp;FR AOC, and nearshore and submergent marsh habitats.</li> <li>• Important waterfowl migratory bird stopover site, particularly along the west shore, Cat Island Wave Barrier, Duck Creek Delta, and Longtail Point<sup>6</sup>.</li> <li>• During relatively high lake levels, narrow stretches of submergent marshes line the entire border with terrestrial habitats of the west shore.</li> <li>• Open waters surround the Cat Island Wave Barrier, which provides Great Lakes beach habitat, protects the Duck Creek Delta and Peters Marsh wetland complexes, and provides important nesting habitat for colonial nesting birds.</li> </ul>
<b>Natural Habitat Communities and Significant Plants</b> (ordered in terms of ecological importance and size/amount)	<p>Nearly 2,100 ha of the Green Bay Open Water West priority area is <b>Green Bay open water</b> with little to no plant life, with the exception of long stretches of <b>submergent marsh</b> that line nearly all of the terrestrial borders of this priority area and make up 51.6 ha<sup>2,7</sup>. The submergent marshes between the mouth of the Fox River and Duck Creek Delta are dominated by coontail (<i>Ceratophyllum demersum</i>), sago pondweed (<i>Stuckenia pectinata</i>), and Eurasian water-milfoil, (<i>Myriophyllum spicatum</i>)<sup>7</sup>. Leafy pondweed (<i>Potamogeton foliosus</i>) is moderately common behind the westernmost portion of the Cat Island Wave Barrier<sup>7</sup>. Along the southern edge of Peters Marsh are coontail, perennial duckweed (<i>Lemna turionifera</i>), giant pondweed, and leafy pondweed<sup>7</sup>. Dominants along the Malchow/Olson Tract submergent marsh include sago pondweed, Eurasian-watermilfoil, coontail, and common bladderwort (<i>Utricularia vulgaris</i>), while Dead Horse Bay has wild celery, bladderwort, coontail, and many others<sup>7</sup>. The open water zone of this priority area often experiences harmful algal blooms in the late summer and early fall<sup>5</sup>.</p> <p>There is also 4.52 ha of <b>Great Lakes beach</b> habitat, which is significant since it is a habitat that is both rare within the LGB&amp;FR AOC and across the state<sup>2,8</sup>. Roughly 2.65 km of Great Lakes beach lines the northern shoreline of Longtail Point and consists of sand and zebra/quagga mussels, though they are also lined with some</p>

<sup>5</sup> Qualls et al. 2013: State of the Bay 2013:  
<http://www.seagrant.wisc.edu/Home/Topics/HabitatsandEcosystems/Details.aspx?PostID=1840>

<sup>6</sup> Epstein et al. 2002

<sup>7</sup> LGB&FR AOC Submerged Aquatic Vegetation Mapping; led by Dr. Amy Wolf and Dr. James Horn

<sup>8</sup> LGB&FR AOC Plant Biodiversity Hotspot Field Effort led by Dr. Amy Wolf, Dr. Robert Howe, and Dr. James Horn

	<p>common reed (<i>Phragmites australis</i>; hereafter referred to as <i>Phragmites</i>)<sup>2</sup>. Native plants that inhabit these shorelines include beach rocket (<i>Cakile edentula</i> var. <i>lacustris</i>), a state special concern species, and cottonwood<sup>8</sup>.</p>
<p><b>Significant Animals</b></p>	<p><b>Birds:</b></p> <ul style="list-style-type: none"> <li>• &gt;100 bird species have been reported in recent years using the open water of the bay of Green Bay and nearshore habitats, including ducks, waterfowl, waterbirds (e.g., gulls, grebes, terns), herons, egrets, shorebirds, and some raptors, during migration, the breeding season, and winter<sup>9</sup>:       <ul style="list-style-type: none"> <li>○ Ducks, waterfowl, and waterbirds, including, but not limited to:           <ul style="list-style-type: none"> <li>▪ Congregate in large groups during migration in the Green Bay Open Water West priority area (based on recent 2016-2017 LGB&amp;FR AOC Migratory Waterfowl Study; surveys done by Tom Prestby):               <ul style="list-style-type: none"> <li>• Common Merganser (<i>Mergus merganser</i>)</li> <li>• Mallard (<i>Anas platyrhynchos</i>), regional priority species from the North American Waterfowl Management Plan</li> <li>• Scaup (Greater, <i>Aythya marila</i> or Lesser, <i>Aythya affinis</i>)</li> <li>• Herring Gull (<i>Larus smithsonianus</i>)</li> <li>• Ring-billed Gull (<i>Larus delawarensis</i>)</li> <li>• American Coot (<i>Fulica americana</i>)</li> <li>• Bonaparte's Gull (<i>Chroicocephalus philadelphia</i>)</li> <li>• Double-crested Cormorant (<i>Phalacrocorax auritus</i>)</li> <li>• Red-breasted Merganser (<i>Mergus serrator</i>)</li> <li>• Ruddy Duck (<i>Oxyura jamaicensis</i>), state special concern species</li> <li>• Canada Goose (<i>Branta canadensis</i>), regional priority species from the North American Waterfowl Management Plan</li> </ul> </li> <li>▪ Other migratory waterfowl species include:               <ul style="list-style-type: none"> <li>• Common Goldeneye (<i>Bucephala clangula</i>), a state special concern species</li> <li>• American Black Duck (<i>Anas rubripes</i>), a state special concern species and listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern and regional priority species from the North American Waterfowl Management Plan</li> <li>• Bufflehead (<i>Bucephala albeola</i>)</li> <li>• Pied-billed Grebe (<i>Podilymbus podiceps</i>), listed on the Upper Mississippi River/Great Lakes Waterbird Conservation Plan</li> <li>• Green-winged Teal (<i>Anas carolinensis</i>)</li> <li>• Common Loon (<i>Gavia immer</i>)</li> <li>• Horned Grebe (<i>Podiceps auritus</i>), state special concern species and listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern</li> <li>• Tundra Swan (<i>Cygnus columbianus</i>), regional priority species from the North American Waterfowl Management Plan</li> </ul> </li> </ul> </li> <li>○ Herons/egrets, including, but not limited to:           <ul style="list-style-type: none"> <li>▪ Great Egret (<i>Ardea alba</i>), state threatened and listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern</li> <li>▪ Great Blue Heron (<i>Ardea herodias</i>)</li> </ul> </li> </ul> </li> </ul>

<sup>9</sup> LGB&FR AOC Biota Database: file "AOCBiota\_DB\_ShareableVersion\_20171213.accdb"

- During the breeding season and migration, swallows use nearshore habitats and open water for foraging, particularly over or near the Cat Island Wave Barrier
- On Cat Island Proper (i.e., the original Cat Island that was a part of the historic Cat Island Chain of barrier islands), American White Pelicans (*Pelecanus erythrorhynchos*), Double-crested Cormorants, and Herring Gulls nest in large numbers, though Canada Geese and Mallards occasionally nest there<sup>10</sup>
- Herring Gulls, Ring-billed Gulls, Caspian Terns (*Hydroprogne caspia*), and American White Pelicans nest on the eastern portions of the Cat Island Wave Barrier in relatively large numbers. Killdeer (*Charadrius vociferus*), Canada Geese, and Mallards also nest on this artificial structure<sup>10</sup>
- Annually between 2015 and 2017, Common Terns (*Sterna hirundo*) successfully nested on artificial nesting platforms built and monitored by the WDNR and FWS<sup>10</sup>
  - Common Terns are federally listed as a species of concern and state endangered; they are also listed on the Wisconsin Wildlife Action Plan Species of Greatest Concern watch list and on the Upper Mississippi River/Great Lakes Waterbird Conservation Plan
- Piping Plovers (*Charadrius melodus*) nested in 2016-2017 on the westernmost “cell” of the Cat Island Wave Barrier on the recently placed dredge material
  - Piping Plover is listed as endangered both federally and for the state of Wisconsin; also listed on the Wisconsin Wildlife Action Plan Species of Greatest Concern watch list and on regional/continental priorities from the Upper Mississippi/Great Lakes Joint Venture Shorebird Plan
- Forster’s Terns nested on artificial nesting platforms in 2015 near the Cat Island Wave Barrier; after 2015, they nested in the mouth of Duck Creek and at Longtail Point/Dead Horse Bay<sup>10</sup>
- >30 shorebird species use the open mud flats and edges of the causeway for foraging and stopover habitat<sup>11</sup>

**Fish:**

- >80 fish species have been recorded in the pelagic zone of the lower bay, including<sup>9</sup>:
  - One federally endangered species: chinook salmon (*Oncorhynchus tshawytscha*)
  - Three state special concern species, including: American eel (*Anguilla rostrata*), banded killifish (*Fundulus diaphanus*), and lake sturgeon (*Acipenser fulvescens*)
  - One International Union for Conservation of Nature-listed species as vulnerable (bloater [*Coregonus hoyi*]) and one as endangered (American eel)
  - Two globally list species (G3 = vulnerable): redbside dace (*Clinostomus elongatus*) and lake sturgeon (*Acipenser fulvescens*)
  - Walleye (*Sander vitreus*), which use spawning reefs around Renard Island, the McDonald Marina (mouth of the Fox River), and Joliet Park
  - Bluegill sunfish (*Lepomis macrochirus*)
  - Burbot (*Lota lota*)
  - Gizzard shad (*Dorosoma cepedianum*)
  - Lake trout (*Salvelinus namaycush*)
  - Largemouth bass (*Micropterus salmoides*)
  - Longnose gar (*Lepisosteus osseus*)

<sup>10</sup> Personal communication with Thomas Prestby

<sup>11</sup> Shorebird master’s project by UW-Green Bay graduate student, Thomas Prestby (2016)

	<ul style="list-style-type: none"> <li>○ Muskellunge (<i>Esox masquinongy</i>)</li> <li>○ Northern pike (<i>Esox lucius</i>)</li> <li>○ Pumpkinseed (<i>Lepomis gibbosus</i>)</li> <li>○ Shortnose gar (<i>Lepisosteus platostomus</i>)</li> <li>○ Smallmouth bass (<i>Micropterus dolomieu</i>)</li> <li>○ Yellow perch (<i>Perca flavescens</i>)</li> </ul> <p><b>Mammals:</b></p> <ul style="list-style-type: none"> <li>● Although ~50 mammal species are known or are expected to occur along the west shore (as noted in Roznik 1979)<sup>12</sup>, only a few likely use parts of the Green Bay Open Water West, including muskrat (<i>Ondatra zibethicus</i>), North American river otter (<i>Lontra canadensis</i>), and American mink (<i>Neovison vison</i>)<sup>13,14</sup></li> <li>● Bats also use nearshore airspace for foraging<sup>15</sup></li> </ul> <p><b>Mollusks:</b></p> <ul style="list-style-type: none"> <li>● Within the pelagic zone of the lower bay, the following has been recorded<sup>9</sup>: <ul style="list-style-type: none"> <li>○ Freshwater clams: fingernail clam (<i>Sphaerium</i> sp.), pea clam (<i>Pisidium</i> sp.)</li> <li>○ Three snails: mud bithynia (<i>Bithynia tentaculata</i>), river snail species (<i>Campeloma</i> sp.), and valve species (<i>Valvata</i> sp.)</li> </ul> </li> </ul> <p><b>Arthropods:</b></p> <ul style="list-style-type: none"> <li>● Several species have been recorded in the pelagic zone of the lower bay in the 1990s, including: <ul style="list-style-type: none"> <li>○ Long-horn caddisfly (<i>Oecetis</i> sp.)<sup>9</sup></li> <li>○ Buzzer midge (<i>Chironomus plumosus</i>)<sup>9</sup></li> <li>○ Green midge (<i>Tanytarsus</i> sp.)<sup>9</sup></li> <li>○ Riffle beetle species (<i>Ordobrevia</i> sp.) from 2007<sup>9</sup></li> </ul> </li> </ul> <p><b>Annelids:</b></p> <ul style="list-style-type: none"> <li>● Aquatic oligochaete worms have been recorded in the pelagic zone of the lower bay in the early 1990s, including<sup>9</sup>: <ul style="list-style-type: none"> <li>○ <i>Aulodrilus americanus</i></li> <li>○ <i>Dero digitata</i></li> <li>○ <i>Nais pardalis</i></li> <li>○ <i>Potamothrix moldaviensis</i></li> <li>○ <i>Nais communis</i></li> </ul> </li> </ul>
<b>Habitat Quality</b>	<p>Overall, the ecological quality of the entire lower bay of Green Bay is relatively poor. The LGB&amp;FR AOC was originally listed as a Great Lakes Area of Concern in 1988 due to poor water quality, contaminated sediments, and degraded or lost habitat.</p> <p>Qualls et al. (2013) assessed the status of the bay of Green Bay using several water quality parameters and a few other elements as described in their 2012 Green Bay Indicator Assessment from the 2013 “State of the Bay” report<sup>5</sup>. On a scale ranging from “poor” to “good,” elements that received a “poor” rating include total phosphorus (unchanging trend), total suspended solid (unchanging trend), Chlorophyll a (unchanging trend), water clarity (unchanging trend), toxic contaminants, aquatic invasive species (deteriorating trend), and benthic macroinvertebrates (undetermined trend)<sup>5</sup>. Nitrates received a “fair-good” rating with a deteriorating trend. Ammonia earned a “good” rating with an unchanging trend<sup>5</sup>. The lower bay also experiences summer and late fall blooms of harmful algae<sup>5</sup>.</p>

<sup>12</sup> Green Bay West Shores Master Plan Concept Element 1979 by Roznik et al.

<sup>13</sup> Wisconsin Department of Natural Resources Technical Report PUB-LF-073

<sup>14</sup> Wisconsin Department of Natural Resources 2015 muskrat house survey

<sup>15</sup> Jeremiah Shrovnal's LGB&FR AOC Bat Study 2016

	<p>Between 1986 and 2013, NEW Water reported that the LGB&amp;FR AOC's total phosphorus and total suspended solids were nearly always above the total maximum daily load (TMDL) targets, while water clarity (using secchi) was lower than the TMDL target<sup>16</sup>.</p> <p>Important changes in fish and waterfowl habitat within the western half of the pelagic zone, however, will likely change over the next several years due to recent construction of the Cat Island Wave Barrier despite the bay's poor water quality. Like the historic Cat Island Chain of islands, this new structure provides Peters Marsh and the Duck Creek Delta with much needed protection from wave action, which may allow for the once extensive submergent and emergent marshes to form again.</p>
<p><b>Significant Invasive Species Issues</b></p>	<p><b>Invasive Plant Species:</b> Each of these species outcompetes and crowds out native plants<sup>2,7,8</sup>:</p> <ul style="list-style-type: none"> <li>• Eurasian water-milfoil (<i>Myriophyllum spicatum</i>) <ul style="list-style-type: none"> <li>○ Found within some of the submergent marsh</li> </ul> </li> <li>• Common reed (<i>Phragmites australis</i>) <ul style="list-style-type: none"> <li>○ Occurs along Great Lakes beach habitat along the northern shoreline of Longtail Point; some management has occurred in recent years</li> </ul> </li> </ul> <p><b>Invasive Animal Species:</b></p> <ul style="list-style-type: none"> <li>• Fish<sup>9</sup> <ul style="list-style-type: none"> <li>○ Alewife (<i>Alosa pseudoharengus</i>)<sup>17</sup> <ul style="list-style-type: none"> <li>▪ Poses a threat to native fish species by consuming zooplankton and disturbing the natural food web; not currently being managed</li> </ul> </li> <li>○ Common carp (<i>Cyprinus carpio</i>)<sup>18</sup> <ul style="list-style-type: none"> <li>▪ Destroy vegetation by uprooting plants and increasing cloudiness of water; not currently being managed</li> </ul> </li> <li>○ Rainbow smelt (<i>Osmerus mordax</i>)<sup>19</sup> <ul style="list-style-type: none"> <li>▪ Negatively affect uncommon to rare native fish species; not currently being managed</li> </ul> </li> <li>○ Round goby (<i>Neogobius melanostomus</i>)<sup>20</sup> <ul style="list-style-type: none"> <li>▪ Prey on small native fish and eggs (e.g., darters) and outcompete similarly sized native fish; not currently being managed</li> </ul> </li> <li>○ White perch (<i>Morone americana</i>)<sup>21</sup> <ul style="list-style-type: none"> <li>▪ Prey on native fish eggs, such as walleye; not currently being managed</li> </ul> </li> </ul> </li> <li>• Freshwater mussels <ul style="list-style-type: none"> <li>○ Zebra mussel (<i>Dreissena polymorpha</i>)<sup>22</sup></li> </ul> </li> </ul>

<sup>16</sup> NEW Water: Report on Water Quality for Lower Green Bay Fox River and East River for Field Year 2013: [http://newwater.us/media/167545/Annual-Report-2013\\_Final-Draft\\_11-17-16.pdf](http://newwater.us/media/167545/Annual-Report-2013_Final-Draft_11-17-16.pdf)

<sup>17</sup> Fuller, P., E. Maynard, D. Raikow, J. Larson, A. Fusaro, and M. Neilson. 2016. *Alosa pseudoharengus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. <https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=490> Revision Date: 9/25/2015. Accessed 17 Oct 2016

<sup>18</sup> Nico, L., E. Maynard, P.J. Schofield, M. Cannister, J. Larson, A. Fusaro, and M. Neilson. 2016. *Cyprinus carpio*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. <https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=4> Revision Date: 7/15/2015. Accessed 17 Oct 2016

<sup>19</sup> Fuller, P., E. Maynard, J. Larson, A. Fusaro, T.H. Makled, and M. Neilson. 2016. *Osmerus mordax*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. <https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=796> Revision Date: 9/29/2015. Accessed on 17 Oct 2016

<sup>20</sup> Fuller, P., A. Benson, E. Maynard, M. Neilson, J. Larson, and A. Fusaro. 2016. *Neogobius melanostomus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. <https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=713> Revision Date: 1/7/2016. Accessed on 17 Oct 2016

<sup>21</sup> Fuller, P., E. Maynard, D. Raikow, J. Larson, A. Fusaro, and M. Neilson. 2016. *Morone americana*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. <https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=777> Revision Date: 1/15/2016. Accessed on 17 Oct 2016

<sup>22</sup> Wisconsin Department of Natural Resources Technical Report PUBL ER-818 2010: file "WDNR2010\_RapidEcologicalAssmtForGBWestShores WildlifeArea.pdf"

	<ul style="list-style-type: none"> <li>▪ Poses threat to native freshwater mussels; not currently being managed</li> </ul>
<p><b>Management and Restoration Recommendations</b></p>	<ul style="list-style-type: none"> <li>• Control introduced plant species (e.g., Eurasian watermilfoil) and maintain extensive and high quality submerged aquatic vegetation with native plants.</li> <li>• Develop or restore important fish spawning and nursery habitats, such as rocky reefs, gravel, cobble, woody debris, and sandy areas, for shoreline fish, along the shoreline.</li> <li>• Continue efforts to re-introduce <i>Hexagenia</i> (mayfly).</li> <li>• Conduct inventory for remnant freshwater mussel beds and translocate/reintroduce populations at favorable locations. Use published studies (e.g., Morales et al. 2006) to identify optimal sites for re-introduction.</li> <li>• Aggressively remove invasive species and restore low shorelines at river mouths of west shore tributaries.</li> <li>• Identify critical buffer habitats and shorelines with potential den sites for mink, otter, and other shoreline wildlife species.</li> <li>• Implement Upper Fox, Wolf, and Lower Fox basin's total maximum daily loads (TMDL) to improve water quality.</li> <li>• Promote best management practices and innovative nutrient management measures in Fox River watershed.</li> <li>• Reduce unimpeded flow of toxins, nutrients, and sediments from urban/suburban storm water discharge pipes.</li> <li>• Implement effective non-point source pollution management plans in smaller watersheds and drainages.</li> <li>• See the Cat Island priority area narrative for project recommendations that relate to the Cat Island Wave Barrier.</li> </ul>
<p><b>Reference Links and Documents</b></p>	<p><b>Web Links:</b></p> <ul style="list-style-type: none"> <li>• Fox 11 video on Green Bay poor water quality (including interview with Dr. Val Klump): <ul style="list-style-type: none"> <li>◦ <a href="http://fox11online.com/news/fox-11-investigates/fox-11-investigates-poor-water-quality-plaquiring-green-bay">http://fox11online.com/news/fox-11-investigates/fox-11-investigates-poor-water-quality-plaquiring-green-bay</a></li> </ul> </li> <li>• NEW Water's Aquatic Monitoring Program: <a href="http://newwater.us/programs-initiatives/aquatic-monitoring-program/">http://newwater.us/programs-initiatives/aquatic-monitoring-program/</a></li> <li>• WDNR's Surface Water Data Viewer: <a href="https://dnrgis.wi.gov/H5/?Viewer=SWDV">https://dnrgis.wi.gov/H5/?Viewer=SWDV</a></li> <li>• NOAA's Lake Level Viewer: <a href="https://coast.noaa.gov/digitalcoast/tools/llv.html">https://coast.noaa.gov/digitalcoast/tools/llv.html</a></li> <li>• TMDL and Watershed Management Plan for Total Phosphorus and Total Suspended Solids in the Lower Fox River Basin and Lower Green Bay: <a href="http://www.uwgb.edu/watershed/REPORTS/Related_reports/TMDLs/LFR_TMDL_EPA_Submittal_Aug_2011.PDF">http://www.uwgb.edu/watershed/REPORTS/Related_reports/TMDLs/LFR_TMDL_EPA_Submittal_Aug_2011.PDF</a></li> <li>• "Dead zones haunt Green Bay as manure fuels algae blooms" (article by the <i>Journal Sentinel</i>): <a href="http://archive.jsonline.com/news/wisconsin/dead-zones-haunt-green-bay-as-manure-fuels-algae-blooms-die-offs-b99344902z1-274684741.html/">http://archive.jsonline.com/news/wisconsin/dead-zones-haunt-green-bay-as-manure-fuels-algae-blooms-die-offs-b99344902z1-274684741.html/</a></li> <li>• Lower Fox Demonstration Farms Network: implementing farming best management practices in the lower Fox River watershed: <a href="https://fyi.uwex.edu/foxdemofarms/about-us/where-we-work/">https://fyi.uwex.edu/foxdemofarms/about-us/where-we-work/</a></li> <li>• Nonpoint Source Control Plan for the Duck, Apple, and Ashwaubenon Creeks Priority Watershed Project: <a href="http://dnr.wi.gov/topic/nonpoint/documents/9kep/Duck_Apple_Ashwaubenon_Creeks-Plan.pdf">http://dnr.wi.gov/topic/nonpoint/documents/9kep/Duck_Apple_Ashwaubenon Creeks-Plan.pdf</a></li> <li>• Wild rice seeding in the lower bay of Green Bay, led by Dr. Amy Carrozzino-Lyon: <a href="http://www.ducks.org/conservation/glar/wisconsin/green-bay-partnership-to-improve-wildlife-habit-water-quality">http://www.ducks.org/conservation/glar/wisconsin/green-bay-partnership-to-improve-wildlife-habit-water-quality</a></li> <li>• 1845 Map of Green Bay, which shows the historic barrier islands: <a href="http://s3.amazonaws.com/labaye/data/1845%20Head%20Of%20Green%20Bay.pdf">http://s3.amazonaws.com/labaye/data/1845%20Head%20Of%20Green%20Bay.pdf</a></li> </ul>

	<p><b>Reference Documents:</b></p> <ul style="list-style-type: none"> <li>• Cedillo, P.E. 2015. Hydrodynamic Modeling of the Green Bay of Lake Michigan Using the Environmental Fluid Dynamics Code. UW-Milwaukee Master's Thesis. Major Advisor: Dr. Hector Bravo. <ul style="list-style-type: none"> <li>◦ <a href="https://dc.uwm.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&amp;httpsredir=1&amp;article=2047&amp;context=etd">https://dc.uwm.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&amp;httpsredir=1&amp;article=2047&amp;context=etd</a></li> </ul> </li> <li>• Chow-Fraser P. 2006. Development of the wetland Water Quality Index for assessing the quality of Great Lakes coastal wetlands. In: Simon TP, Stewart PM (eds) Coastal wetlands of the Laurentian Great Lakes: health, habitat and indicators. Indiana Biological Survey, Bloomington, IN, pp 137-166.</li> <li>• Disterhaft, K. 2013. Changes in fish assemblages of Lake Michigan's Green Bay following the introduction of Dreissenid mussels and round goby (<i>Neogobius melanostomus</i>) during 1980-2010. Master's thesis from the University of Wisconsin-Green Bay.</li> <li>• Hamidi, S.A., H.R. Bravo, J.V. Klump, and J.T. Waples. 2015. The role of circulation and heat fluxes in the formation of stratification leading to hypoxia in Green Bay, Lake Michigan. <i>Journal of Great Lakes Research</i> 41:1024-1036.</li> <li>• Harris, V.A. 1998. Waterfowl use of lower Green Bay before (1977-78) and after (1994-97) zebra mussel invasion. Master's thesis from the University of Wisconsin-Green Bay.</li> <li>• Klump, J.V., D.N. Edgington, P.E. Sager, and D.M. Robertson. 1997. Sedimentary phosphorus cycling and a phosphorus mass balance for the Green Bay (Lake Michigan) ecosystem. <i>Canadian Journal of Fisheries and Aquatic Sciences</i> 54:10-26.</li> <li>• Qualls, T., H.J. Harris, and V. Harris. 2013. The State of the Bay: The Condition of Green Bay/Lake Michigan 2013. University of Wisconsin Sea Grant Institute.</li> <li>• Wisconsin Department of Natural Resources. 2014. Green Bay Planning Group Master Plan. Technical Report PUB-LF-075.</li> </ul>
<p><b>Site History</b> (e.g., original vegetation, past conservation projects)</p>	<p>In the early 1630s, Frenchman Jean Nicolet first arrived in lower Green Bay when it was primarily inhabited by Native American tribes<sup>23</sup>. Lower Green Bay consisted of large beds of wild rice (<i>Zizania</i> sp.) and wild celery (<i>Vallisneria americana</i>), extensive emergent marsh (<i>Schoenoplectus</i> sp., cattail), sedge meadows (<i>Calamagrostis canadensis</i>), shrub carr (e.g., <i>Cornus</i> spp., <i>Salix</i> spp.), swamps, and wet conifer forest (black spruce [<i>Picea mariana</i>], balsam fir [<i>Abies balsamea</i>])<sup>24,25,26,27,28</sup>. Between the late 1600s and 1800s, European fur trade, duck hunting, fishing, logging, shipping, and agriculture were important early industries in lower Green Bay<sup>29,30,31</sup>. In the early 1800s, there were a few small settlements and farms of Europeans and Native Americans in the lower Bay<sup>30</sup>. Similar to the fur trade and logging, commercial fishing was an important industry in Green Bay, in which most fishermen primarily harvested</p>

<sup>23</sup> Jean Nicolet: French Explorer. By The Editors of Encyclopaedia Britannica. Available: <https://www.britannica.com/biography/Jean-Nicolet> (accessed on 24 Oct 2016)

<sup>24</sup> Arthur C. Neville's Map of Historic Sites on Green Bay, Wisconsin 1669-1689. Available: <http://s3.amazonaws.com/labaye/data/Bay%20Settlement%20Map%20W1%20Historical%20Bulletin%201926.pdf> (accessed on 24 Oct 2016)

<sup>25</sup> Survey of the N.W. Lakes: East Shore of Green Bay 1843. Available: <http://s3.amazonaws.com/labaye/data/1843%20East%20Shore%20of%20Green%20Bay.jpg> (accessed on 24 Oct 2016)

<sup>26</sup> 1845 Chart of Green Bay. Available <http://s3.amazonaws.com/labaye/data/1845%20Chart%20of%20Green%20Bay.pdf> (accessed on 24 Oct 2016)

<sup>27</sup> 1820s Fox River Military Road Map to Ft. Crawford. Available: <http://s3.amazonaws.com/labaye/data/1820s%20Fox%20River%20Military%20Road%20Map%20to%20Ft.%20Crawford.pdf> (accessed on 24 Oct 2016)

<sup>28</sup> Personal communication with Thomas Erdman

<sup>29</sup> City of Green Bay's History Webpage: <http://www.ci.green-bay.wi.us/history/1800s.html> (accessed on 20 Oct 2016)

<sup>30</sup> Excerpt from "Recollections of Green Bay in 1816-17" by James W. Biddle. Available: <http://s3.amazonaws.com/labaye/data/Recollections%20of%20Green%20Bay%20in%201816-1817.pdf> (accessed on 24 Oct 2016)

<sup>31</sup> The Early Outposts of Wisconsin: Green Bay for Two-Hundred Years, 1639-1839. Available: <http://labaye.org/item/70/2810> (accessed on 25 Oct 2016)

whitefish, lake trout, and lake herring<sup>5,32</sup>. Other fish caught in Brown County in 1888 included perch, pike pickerel, suckers, catfish, muskellunge, and many others<sup>5,33</sup>. Unfortunately, overfishing and other significant anthropogenic changes, such as water pollution caused by the paper industry, led to the decline of many fish species<sup>5,32</sup>.

Historically, there was a chain of barrier islands, called the Cat Island Chain, which extended off the west shore of the bay of Green Bay. Grassy Island (also called Grassy Point) was the easternmost of these islands that used to occur within present day Green Bay Open Water East<sup>35</sup>. Grassy Island had a small forest of cottonwood (*Populus deltoides*) and willow (*Salix* sp.) as well as a bulrush/sedge (*Scirpus-Eleocharis*) marsh<sup>34</sup>. There used to be a shallow sand bar called Point Sable Bar and Frying Pan Shoal that extended from Point au Sable on the eastern shore to Longtail Point on the west shore<sup>26,35,39</sup>. In low water years, Native Americans used to walk on foot from Point Sable to the west shore<sup>39</sup>. It was so shallow in fact that willows and cottonwoods used to grown on Frying Pan Shoal<sup>39</sup>.

Because of these shallow areas in the lower bay and extensive miles-long sand bars, ship navigation was extremely challenging and in some cases nearly impossible<sup>36</sup>. Therefore, in an effort to improve Green Bay shipping access and navigation, Congress provided \$30,500 in funding in 1866 to construct a shipping channel 60.96 m (200 ft) wide and 3.66 m (12 ft) deep that traverses through Grassy Island and in between Longtail Point and the western edge of Point Sable Bar/Frying Pan Shoal<sup>36,37</sup>. Construction began in May the following year and was quickly finished by September 1867<sup>36</sup>. Over the next several decades, the channel was widened and made deeper: June 1896: increased depth to 4.57 m (15 ft); June 1902: increased depth to 5.49 m (18 ft) in the northern channel; June 1910: created a ship turning area that was 4.57 m (15 ft) deep; September 1902: increased depth to 6.10 m (20 ft) in northern channel; March 1925: increased depth of southern channel to 5.49 m (18 ft); and January 1927: increased northern channel depth to 6.40 m (21 ft)<sup>36</sup>. By the early 1930s, the channel was widened again and increased depth to 6.71 m (22 ft)<sup>36</sup>. Today, the channel is anywhere between 7.32 m (24 ft) and 7.92 m (26 ft) and around 152.4 m (500 ft) wide. There used to be a lighthouse on Grassy Island that was first lit on 15 November 1872, though eventually it was relocated to the mainland by the Green Bay Yachting Club Harbor in 1966<sup>38</sup>. A break wall was constructed on the western edge of Lone Tree Island, which is the eastern side of the shipping channel and is visible on Brown County's 1938 air photo, with a house<sup>39</sup>.

During the 1950s, 5,000-6,000 Trumpeter Swans were seen migrating through lower Green Bay by using the offshore waters of Peters Marsh and eating submerged aquatic plants<sup>39</sup>. In the 1970s, they switched to feeding in open fields<sup>39</sup>. In June 1969 and during other visits, UW-Green Bay's Thomas Erdman and WDNR's Harold Mathiak conducted breeding bird censuses in the islands of the lower bay<sup>39</sup>. On the islands west of the shipping channel, they found nesting Black-crowned Night-Herons (*Nycticorax nycticorax*), Snowy Egrets (*Egretta thula*), Great Egrets, Cattle Egrets (*Bubulcus ibis*), Common Terns, Double-crested Cormorants, Herring Gulls, Ring-billed Gulls, and Canada Geese<sup>39</sup>. Unlike the present day, Cat Island Proper used to have willows and cottonwoods growing in the mid-1960s, though eventually the guano

<sup>32</sup> Qualls et al. (2013) cited Kraft, C. 1982. Green Bay's Yellow Perch Fishery. Wisconsin Sea Grant Publication. WIS. SG.82-725

<sup>33</sup> Qualls et al. (2013) cited Smith, H.M. & M.M Snell. 1891. Review of the fisheries of the Great Lakes in 1885. U.S. Commission of Fish & Fisheries

<sup>34</sup> Howlett 1974: The rooted vegetation of west Green Bay with reference to environmental change

<sup>35</sup> NOAA Navigational Chart: [http://www.charts.noaa.gov/BookletChart/14910\\_BookletChart.pdf](http://www.charts.noaa.gov/BookletChart/14910_BookletChart.pdf)

<sup>36</sup> *Green Bay Press Gazette* article from 1934 on increasing the depth of the Green Bay shipping channel; available in David A. Cofrin Library's Special Collections

<sup>37</sup> U.S. Army Corps of Engineers Map of the shipping channel from 1898 and 1898; provided by Thomas Erdman

<sup>38</sup> Wisconsin's Historical Markers: <http://www.wisconsinhistoricalmarkers.com/2012/09/grassy-island-range-lights.html>

<sup>39</sup> Personal communication with Thomas Erdman

of these nesting birds killed the trees<sup>39</sup>. Tom Erdman in particular has spent decades monitoring colonial nesting birds in the lower bay.

During the 1960s, sediment from the bay was dredged to continue maintaining the shipping channel of Green Bay and was subsequently dumped back into open water in areas north of the Cat Island Chain (these dredge dumping areas are visible on the 1938 air photo from the Brown County Online GIS Portal) as well as north of Point Sable Bar<sup>40,41</sup>. In 1974, this practice was banned since the dredge material contained toxic PCBs (polychlorinated biphenyls); therefore, an island-based confined disposal facility was constructed in 1979, called Renard Island (aka Kidney Island), where this dredge material was stored<sup>40</sup>. Renard Island is located north of the Bay Beach Amusement Park and east of the mouth of the Fox River. A causeway was later built that connects the mainland to Renard Island on the island's westernmost section for convenient access. The causeway and Renard Island also altered sediment transport (per UW-Sea Grant's Julia Noordyk)<sup>42</sup>.

Due to extremely high water levels in the bay, massive storms, and recently hardened shorelines (e.g., development), most of the Cat Island Chain of islands washed away during the spring of 1973 with the exception of a few small sandy islands, including Cat Island<sup>43,44</sup>. The huge emergent and submergent marshes of the Duck Creek Delta complex also vanished because the islands no longer provided the much needed protection and due to high sediment loads further upstream<sup>43,44</sup>. These significant changes can easily be viewed on Brown County's 1978 aerial imagery of lower Green Bay. Despite the high water and storms, remnants of Cat Island and a few other tiny islands persisted and are still present today.

In the 1980s, a group of local conservationists proposed the idea of reconstructing these three barrier islands and formalized the idea in the LGB&FR AOC's 1988 Remedial Action Plan<sup>43</sup>. It took decades for that idea to materialize and become a reality, but it finally happened<sup>43</sup>. Over time, the Cat Island Wave Barrier and island "cells" were eventually constructed by May 2013 thanks to a \$1.5 million initial funding opportunity through the Great Lakes Restoration Initiative<sup>43,45</sup>. The long-term vision of this project in terms of restoration is for each "cell" to have upland Great Lakes beach habitat that grades downwards toward the water changing to emergent and submergent marshes, which will provide habitat for many fish species, invertebrates, and birds. Another goal is for the submergent and emergent marshes to return in the Duck Creek Delta wetland complex.

Over the past several decades, the entire bay of Green Bay has been heavily studied by scientists from agencies, non-profit organizations, universities, the Oneida Tribe, and other organizations. The amount of knowledge accrued is truly significant. Below is a selected summary of relatively recent projects:

- WDNR's Tammie Paoli leads a long-term bottom trawling fish monitoring project in the bay of Green Bay that dates back to the 1980s<sup>46</sup>.
- In collaboration with the WDNR, UW-Green Bay graduate student, Katherine Disterhaft, investigated changes in fish assemblages in the bay of Green Bay since the introduction of invasive zebra and quagga mussels and round gobies between 1980 and 2010 for her master's thesis project. Disterhaft used fish data collected by WDNR's Tammie Paoli<sup>46</sup>.

<sup>40</sup> U.S. Army Corps of Engineers 2011: Available:

<http://www.lre.usace.army.mil/Portals/69/docs/PPPM/PlanningandStudies/GBDMMP/GreenBayDMMP2.pdf>

<sup>41</sup> U.S. Army Corps of Engineers map from 1966

<sup>42</sup> LGB&FR AOC Stakeholder Meeting on 23 June 2015

<sup>43</sup> Brown County Port and Resource Recovery Cat Island document:

<https://static1.squarespace.com/static/56ec0372859fd0e272858772/t/574db48fab48de7bc23597a0/1464710289702/2014+Cat+Island+Abstract+Spring.pdf>

<sup>44</sup> Frieswyk and Zedler 2007: "Identifying and characterizing dominant plants as an indicator of community condition."

<sup>45</sup> U.S. Dept. of the Interior Article: <https://www.doi.gov/restoration/restoring-cat-island-chain-green-bay-wisconsin>

	<ul style="list-style-type: none"> <li>• Dr. Patrick Forsythe and Dr. Christopher Houghton have been leading an investigation of coastal wetland-nearshore linkages of Green Bay sport fishes, which also includes invertebrate sampling<sup>46</sup>. They plan to estimate the coastal wetland habitat that is used by sport fish species and to build habitat food webs<sup>46</sup>. They are also looking at spatial and temporal distributions of larval fish in the upper and lower bay<sup>46</sup>.</li> <li>• The U.S. Fish and Wildlife Service coordinates an early detection and monitoring program of aquatic invasive species in Lake Michigan, and many of their sampling locations are in the LGB&amp;FR AOC, including sites in Green Bay Open Water West<sup>46</sup>. They survey for ichthyoplankton, carp, macroinvertebrates, and nearshore fishes<sup>46</sup>.</li> <li>• NEW Water leads a long-term aquatic monitoring program with multiple sampling locations within the LGB&amp;FR AOC as well as other parts of the bay of Green Bay and the Fox River. They collect data on water temperature, dissolved oxygen, pH, phosphorus, nitrogen, turbidity, total suspended solids, and many others<sup>47</sup>.</li> <li>• Aquatic invertebrate data were collected in the bay of Green Bay in 1978, 1988, and 1994 with sampling locations in Green Bay Open Water West (Rades, D.L. and D.F. Sanders. Lower Fox River/Bay of Green Bay Biological Water Quality Study-1994. 1995. Project 5073. Report 1: a report to Group Project 5073 Members and the Wisconsin Department of Natural Resources-Lake Michigan District. Appleton, Wisconsin: Integrated Paper Services, Inc.)</li> <li>• In 2014-2016, UW-Milwaukee's Dr. Jerry Kaster and graduate student Christopher Groff released 120 million eggs of <i>Hexagenia</i> (mayfly) into the bay of Green Bay in an attempt to reintroduce mayflies into the Green Bay ecosystem. In 2016, adult exuviae were found in 2016 at Longtail Point, Little Tail Point, and Sturgeon Bay.</li> <li>• Establishing wild rice in the bay of Green Bay (2017-2018), including seeding in Peters Marsh; project led by Dr. Amy Carrozzino-Lyon (UW-Green Bay), Dr. Patrick Robinson (UW-Green Bay), Dr. Mathew Dornbush (UW-Green Bay), and Brian Glenzinski (Ducks Unlimited).</li> <li>• In the fall of 2017, the UW-Green Bay's Cofrin Center for Biodiversity's (CCB) Dr. Amy Wolf, Dr. James Horn, and Dr. Robert Howe mapped submerged aquatic plant beds throughout the LGB&amp;FR AOC<sup>7</sup>.</li> <li>• Terrence Lychwick conducted a walleye study between 1983 and 1987, in which he stocked walleye fingerlings and conducted surveys along the east shore of Green Bay between Pt. Sable and Henderson's Point (Little Sturgeon Bay) and the west shore between Duck Creek and Menominee River<sup>48</sup>.</li> <li>• For her UW-Green Bay master's thesis project (completed 1998), Vicky Harris investigated waterfowl use of lower Green Bay both before (1977-1978) and after (1994-1997) the zebra mussel invasion in the 1990s.</li> <li>• In 2016-2017, under the guidance of CCB's Dr. Howe, Dr. Wolf, and Erin Giese, Tom Prestby surveyed migratory waterfowl within the LGB&amp;FR AOC and mapped rafts. Within Green Bay Open Water West, two sampling locations are on the Cat Island Wave Barrier, and a third is located on the west shore overlooking Longtail Point.</li> <li>• Since 1997, the Oneida Tribe has conducted continuous water monitoring with USGS in Duck Creek<sup>50</sup>.</li> <li>• Surface Water Integrated Monitoring System (SWIMS): holds chemistry (water, sediment, fish tissue), physical, and biological (macroinvertebrate, aquatic invasives) data: <a href="http://dnr.wi.gov/topic/surfacewater/swims/">http://dnr.wi.gov/topic/surfacewater/swims/</a></li> <li>• Dr. Val Klump has spent a significant part of his career studying Green Bay water quality issues. <ul style="list-style-type: none"> <li>○ <a href="http://waterbase.uwm.edu/docs/Klump_Fermanich_2017_FinalReport_NA10NOS4780139_26Jan2017.pdf">http://waterbase.uwm.edu/docs/Klump_Fermanich_2017_FinalReport_NA10NOS4780139_26Jan2017.pdf</a></li> </ul> </li> </ul>
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<sup>46</sup> Green Bay Fish Working Group Annual Meetings on 20 March 2015, 6 January 2016, and 4 January 2017

<sup>47</sup> NEW Water Aquatic Monitoring Program: <http://newwater.us/programs-initiatives/aquatic-monitoring-program/>

<sup>48</sup> Personal communication with WDNR's Steve Hogler

	<ul style="list-style-type: none"> <li>• UW-Extension is leading the Lower Fox Demonstration Farms Project, whose goal is to implement agricultural best management practices to reduce nutrient runoff that is carried into the Fox River and ultimately the lower bay<sup>49</sup>.</li> <li>• The Northeast Wisconsin Land Trust's Green Bay and Lower Fox Project involves identifying high priority land parcels that could potentially improve water quality through conservation easements, etc.<sup>50</sup>.</li> <li>• Green Bay Ecosystem Modeling, UW-Extension's Chad Cook<sup>50</sup>.</li> <li>• Management Analysis Tool, which looks at how climate and landscape conservation can impact Green Bay water quality (Dr. Kevin Fermanich)<sup>50</sup>.</li> </ul> <p>The bay of Green Bay provides significant and in most cases rather critical habitat for many fish species, aquatic invertebrates, waterfowl, waterbirds, and freshwater mussels that reside within the LGB&amp;FR AOC. Water quality is relatively poor due to high nutrient and sediment loadings in the bay and pollution. Like other bodies of water, the bay has experienced (and in some cases still experiences) harmful algal blooms, fish kills, and avian botulism<sup>5,51,52,53</sup>. However, despite the poor water quality, other structural improvements, restoration efforts, and in some cases monitoring and species re-introduction are needed in the bay. Restoration of shoreline fish spawning and nursery habitats, such as rocky reefs, gravel, cobble, woody debris, and sandy areas, is needed. Reintroductions of freshwater mussels and improvements to shoreline habitat and den sites for mink and otter could furthermore be made. Efforts should continue to be made to re-introduce <i>Hexagenia</i> in the bay. Hopefully, the Cat Island Wave Barrier will promote the revival of the once extensive submergent and emergent marshes of the Duck Creek Delta. To improve water quality, implementing best management practices for agriculture and TMDLs for the Upper Fox, Wolf, and Lower Fox basins will be necessary.</p> <p>There is no doubt a significant amount of work is needed in the bay, however, thankfully there is a large cohort of scientists, biologists, policy makers, land managers, and concerned citizens actively seeking ways to improve the Green Bay ecosystem.</p>
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<sup>49</sup> Lower Fox Demonstration Farms Network: <https://fyi.uwex.edu/foxdemofarms/about-us/where-we-work/>

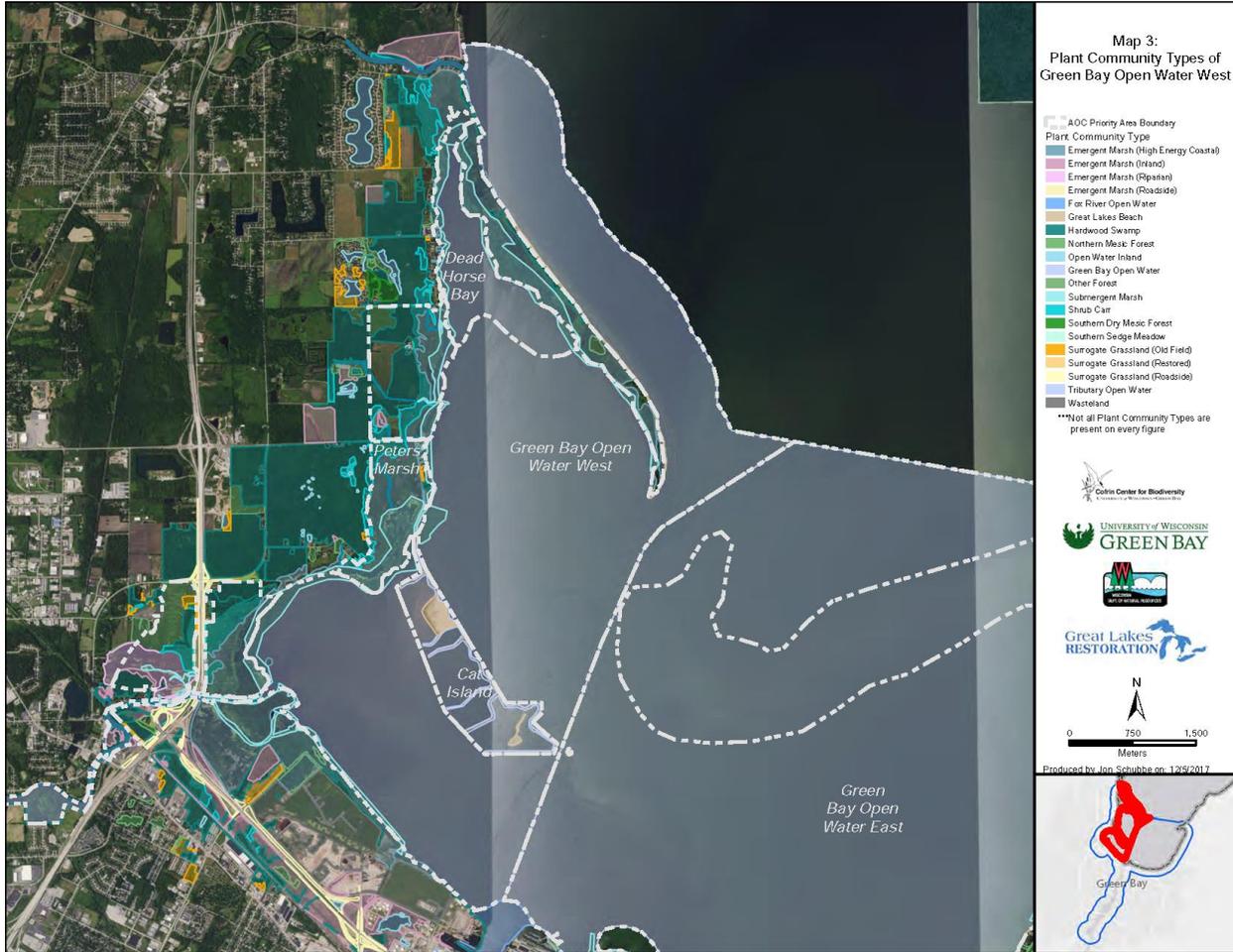
<sup>50</sup> AOC Conservation Project Catalogue

<sup>51</sup> Silliman et al. 2001: "A hypothesis for the origin of perylene based on its low abundance in sediments of Green Bay, Wisconsin"

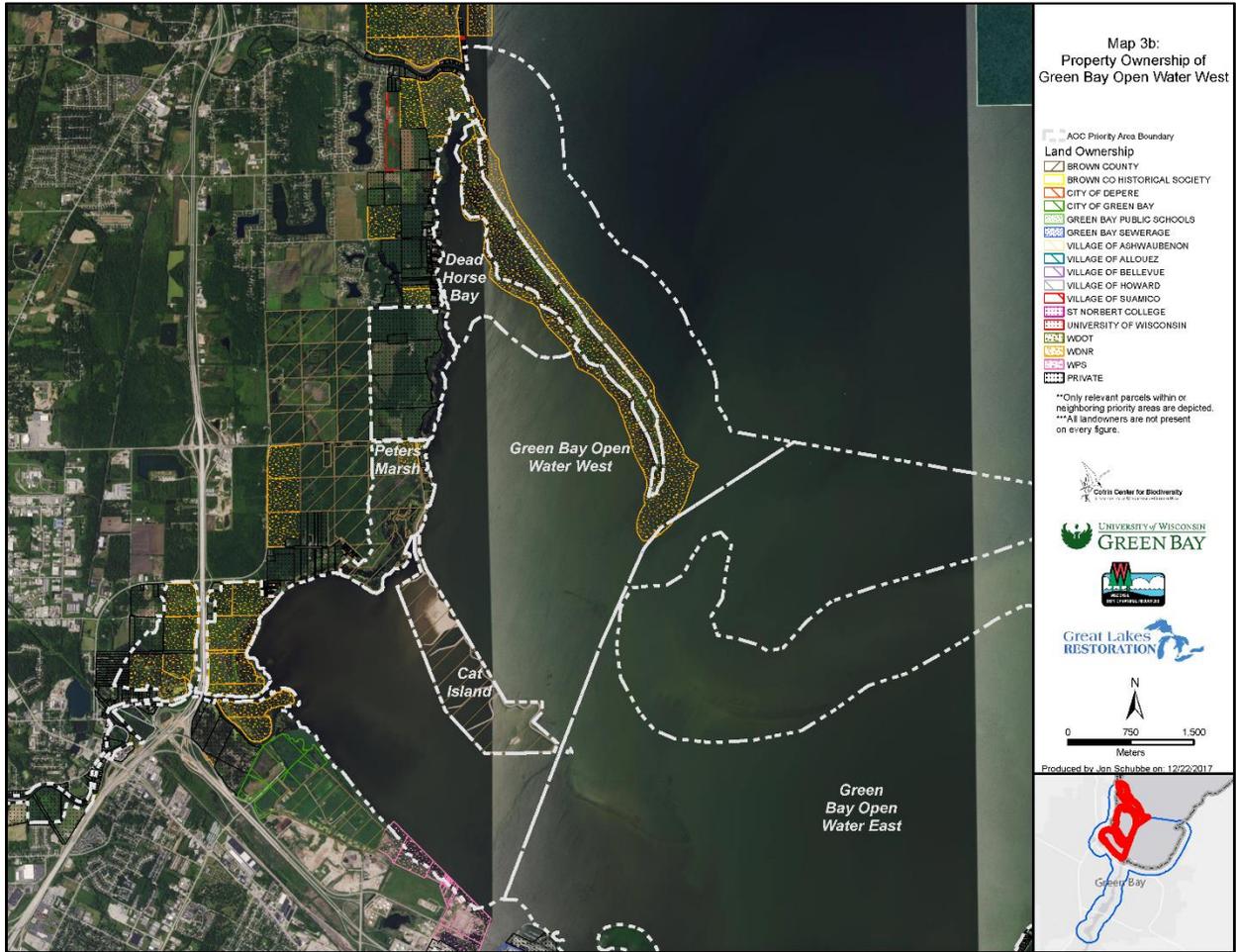
<sup>52</sup> Smith et al. 1988: "Estuary Rehabilitation: The Green Bay Story"

<sup>53</sup> Brand et al. 1983: Waterbird mortality from botulism type E in Lake Michigan: an update"

Map of Green Bay Open Water West plant communities, which are delineated based on the UW-Green Bay 2015 habitat mapping effort and 2017 submerged aquatic vegetation surveys. Map made by UW-Green Bay's Jon Schubbe.



Map of land ownership for Green Bay Open Water West. Map made by UW-Green Bay's Jon Schubbe.



Photograph of the southern portion of Green Bay Open Water West. Photograph taken by Erin Giese on 2 December 2016 facing west.



The shipping channel is located in between the easternmost “cell” of the Cat Island Wave Barrier (left) and Lone Tree Island (center). Photograph taken by Erin Giese on 2 December 2016 facing west.

