Part 1 of the Final Report for the

Lower Green Bay & Fox River Area of Concern Habitat Restoration Plan and Path Toward Delisting Project

Submitted to the Wisconsin Department of Natural Resources
and the U.S. Environmental Protection Agency

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Acronyms: UW-Green Bay's Cofrin Center for Biodiversity (CCB), The Nature Conservancy (TNC), U.S. Environmental Protection Agency (USEPA), U.S. Fish and Wildlife Service (USFWS), and Wisconsin Department of Natural Resources (WDNR).

Throughout this project, we collaborated with The Nature Conservancy (TNC; Nicole Van Helden, Michael Grimm, Nicholas Miller, and John Wagner), who has worked to identify ways to improve fish and wildlife habitats and populations within the surrounding watershed of the Lower Green Bay and Fox River Area of Concern. Please read Part 2 of this project's final report for more information on TNC's efforts.

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EXECUTIVE SUMMARY

- The Lower Green Bay and Fox River Area of Concern (LGB&FR AOC) is one of the most ecologically diverse regions in the Laurentian Great Lakes. Its geographic position at the terminus of a large north-south embayment and the productive estuarine environment created by drainage from the extensive Fox-Wolf River watershed make this AOC a magnet for migratory species and a critical area for fisheries and wildlife populations.

- The same landscape factors that make this region so significant also contribute to its ecological vulnerability. Habitat loss, destructive spread of invasive species, and water pollution by toxins, sediments, and excessive nutrients have combined to transform the lower Green Bay and Fox River ecosystem into a mosaic of developed lands and mostly degraded natural habitats.

- Despite centuries of human impacts, however, nearly 42% of the land or wetland area within 1 km of the Green Bay/Fox River shoreline can be classified as natural or semi-natural habitat, capable of supporting productive ecological communities and desirable fish and wildlife populations.

- Aquatic habitats in lower Green Bay and the Fox River also are ecologically viable and support economically valuable species, even though water quality has been severely degraded and invasive species have permanently altered the structure of food webs and ecosystem dynamics.

- The purpose of this document is to outline a framework for reversing two beneficial use impairments (BUIs) in the LGB&FR AOC: 1) degradation of fish and wildlife populations and 2) loss of fish and wildlife habitat. Our specific goal is to formulate recommendations for restoring fish and wildlife habitats and populations and to provide an objective, quantitative mechanism for tracking progress toward a condition where removal of these BUIs can be justified.

- Our recommendations build on work during the past three decades by citizen advisory groups; professional staff from the Wisconsin Department of Natural Resources, U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency, University of Wisconsin Sea Grant, Oneida Nation, Brown County, U.S. Geological Survey, City of Green Bay, City of De Pere, Village of Allouez, U.S. Army Corps of Engineers, and other government entities; conservation biologists from The Nature Conservancy, NEW Water, Bay-Lake Regional Planning Commission, Fox-Wolf Watershed Alliance, and other organizations; faculty, staff, and student researchers from the University of Wisconsin-Green Bay and other universities; environmental consultants, including Applied Ecological Services; and policy-makers at every level of government.

- We provide background resources to inform the decision-making process:
  - an online digital map of habitat remnants and potentially restorable lands
  - a database describing natural communities and species present in the LGB&FR AOC
  - a catalog of historical and ongoing conservation projects
  - results from recent field surveys of remnant natural habitats, plant "biodiversity hotspots," submerged aquatic vegetation, breeding birds, anurans (frogs and toads), bats, migratory waterfowl, and odonates (dragonflies and damselflies)

    - a collection of recent digital photographs of all significant habitat remnants within 1 km of the LGB&FR AOC shoreline; at least one photograph from each area is geotagged and annotated with field notes
    - a digital bibliography of publications and reports relevant to fish and wildlife habitats and populations in the LGB&FR AOC
    - a list describing major information gaps
    - notes and presentations from at least 17 meetings of stakeholders and other contributors during the three-year duration of this project (2015-2017)

- We identified **18 habitat types** in the LGB&FR AOC using the natural community classification scheme developed by the Natural Heritage Program of the Wisconsin Department of Natural Resources. Several community types were subdivided to recognize important local features, such as the open water region of Green Bay and the Fox River and different types of emergent wetlands.

- Other than open water habitats, the most extensive habitats in the LGB&FR AOC today are hardwood swamp (764 ha), coastal emergent marsh (348 ha), submergent marsh/submerged aquatic vegetation (249 ha), and inland emergent marsh (170 ha). Early successional forest and woodlands (173 ha), and surrogate grasslands, including old fields and other uncultivated grasslands (140 ha), are the only other habitat categories that are represented by more than 100 ha.

- Two imperiled habitats, undeveloped Great Lakes beach and southern sedge meadow, were once widespread in the LGB&FR AOC but today are represented by only small remnants.

- Twelve fish and wildlife species that regularly occur in the LGB&FR AOC as breeders or migrants are officially listed as endangered or threatened, including the federally endangered Piping Plover (*Charadrius melodus),* federally-threatened Red Knot (*Calidris canutus*), and recently federally listed rusty patched bumble bee (*Bombus affinis*). Another 50 species are listed in Wisconsin as state special concern, and at least 11 others are identified as conservation priorities by one or more non-profit conservation organizations. These species, plus others that have been shown to be vulnerable to human disturbance, were combined into 19 groups of ecologically similar species such as “colonial breeding waterbirds,” “tributary fish,” “anurans,” and “coastal wetland aquatic macroinvertebrates.” Three species of special interest or importance (Piping Plover, muskrat, and wintering Bald Eagles (*Haliaeetus leucocephalus*) were listed uniquely. This list of **22 fish and wildlife species/species groups** includes all taxa identified as conservation targets by previous Remedial Action Plans for the LGB&FR AOC.

- All 18 habitat types and 22 species/species groups were assigned weights of relative importance based on objective criteria such as historical significance in the LGB&FR AOC, dependence on the Green Bay/Fox River aquatic ecosystem, and economic or ecological importance.

- For each habitat type and species/species group, we devised a method for measuring current and future condition, converted to a standardized condition score ranging from 0 (worst case) to 10 (best case). Expert opinions from professional biologists were solicited to establish a current score or **baseline condition**.

- Weightings for each element were combined with the corresponding baseline conditions to calculate a **weighted average** for each of the two BUI categories (fish and wildlife habitats and fish and wildlife populations), again ranging from 0 (worst case) to 10 (best case). The baseline condition (weighted average) for fish and wildlife habitats (3.60) was lower than the baseline condition for fish and wildlife populations (4.65) in the LGB&FR AOC.

- Weightings and baseline condition scores were imbedded in a MS Excel worksheet (assessment tool) for each BUI. These assessment tools permit users to explore many alternative scenarios for improving the overall current condition of fish and wildlife habitats and fish and wildlife population BUIs in the LGB&FR AOC.

- We used these computerized tools, guided by input from stakeholders and expert biologists, to identify realistic quantitative targets for justifying the removal of the respective BUIs. Based on these analyses, we recommend a **target of 6.0** for the removal of the fish and wildlife habitat BUI and **6.5** for removing the fish and wildlife population BUI.

- For each habitat and species/species group, we provide a narrative describing the reasons for our assigned weighting and baseline score, a proposed metric for assessing current condition and tracking progress towards a desired future condition, and recommendations for management actions that are likely to improve the condition score.

- We also present a portfolio of **priority areas** where conservation actions will most likely yield multiple improvements in the condition of fish and wildlife habitats and populations. Progress toward the removal targets inevitably will require habitat improvements or species conservation measures in these areas.

- We published a **website** that features an online GIS portal that displays our mapped plant communities, historical information, and wildlife data, provides summaries of fish and wildlife habitats and species/species groups (including field data and photographs), provides links to download our MS Excel assessment tools, Biota Database, Conservation Project Catalogue, and reference materials.
    - http://www.uwgb.edu/green-bay-area-of-concern/

- In addition to the prescribed deliverables, this project has contributed meaningfully to the education of 28 UW-Green Bay student assistants who were integral parts of the project from the beginning. Both undergraduate and graduate students contributed substantially to the outcomes by conducting field surveys, creating GIS maps, assisting with data management, collecting historical information, assembling reference databases, and building the project website.

- A major implication of our analysis is that ecologically significant improvements in fish and wildlife habitats and populations are feasible in the LGB&FR AOC, and the removal of wildlife-related BUIs can be justified if these improvements are systematically implemented and tracked. Our assessment tools illustrate that multiple paths toward BUI removal are possible, facilitating a collaborative strategy that involves many stakeholders and contributors.

- We emphasize that our BUI removal framework welcomes adjustments as better information becomes available, as it surely will. Our recommended metrics, baseline condition scores, weightings, and BUI removal targets are intended to be starting points, not rigid prescriptions, for restoring fish and wildlife habitats and populations in the LGB&FR AOC.

INTRODUCTION

The Great Lakes Water Quality Agreement (GLWQA), signed in 1972 by the United States and Canada, aims to restore the "chemical, physical, and biological integrity of the Great Lakes Basin Ecosystem" (Botts and Muldoon 2005, Krantzberg 2007). The agreement is administered by the International Joint Commission (IJC), which has provided increasingly specific recommendations for achieving the original goals of the agreement, including constructive collaborations among state, provincial, and local agencies. In 1987, the IJC adopted a protocol for designating Great Lakes "Areas of Concern" (AOCs), sites where local water resources and ecosystem integrity have become severely degraded due to pollutants, habitat destruction, and other factors (Hartig and Law 1994). To date, U.S. and Canadian governments have identified 43 AOCs, re-defined in 2012 as "geographic areas designated by the Parties where significant impairment of beneficial uses has occurred as a result of human activities at the local level" (Grover and Krantzberg 2015). The AOC listing is based on a list of one or more beneficial use impairments (BUIs) such as "degradation of fish and wildlife populations," "eutrophication or undesirable algae," "degradation of aesthetics," and "fish tumors or other deformities." Additionally, the 2012 revisions acknowledged broader threats such as climate change and aquatic invasive species and noted the need to improve AOC governance, including engagement of First Nations governments (Grover and Krantzberg 2015).

An assigned government agency leads the development of a Remedial Action Plan (RAP) for each AOC. The RAP process involves three stages: First, the nature and severity of environmental degradation and BUIs in the AOC are identified. Next, the responsible agency and citizen advisory teams formulate goals and recommendations for reversing the degradation. Finally, the recommendations are implemented through projects and management actions. The third stage requires an assessment framework that validates the accomplishment of RAP goals (Hauserman 2015).

As of 2017, seven of the 43 AOCs have been officially delisted, and significant progress has been made on removing individual BUIs in many of the remaining AOCs. BUI removal justifications vary considerably, however, and assessment criteria are being pioneered independently across the Great Lakes (Grapentine 2009, Macacek and Grabas 2011, Michigan Department of Environmental Quality 2015, Bellinger et al. 2016, Angradi et al. 2017). The challenge of setting objective, quantitative ecological restoration targets is not unique to the Laurentian Great Lakes. Bernhardt et al. (2007), noted that efforts to restore rivers and streams in the U.S. are usually followed by no measurable criteria for success. Metrics are typically limited to general appearance and positive public opinion, although more recent assessment standards appear to be improving (Wortley et al. 2013). Government policy generally provides little objective guidance for ecological restoration, despite the fact that government agencies annually invest millions and possibly billions of dollars in environmental rehabilitation efforts (Palmer and Ruhl 2015).

This report describes an objective, quantitative method for setting restoration targets and assessing progress toward these targets in the Lower Green Bay and Fox River Area of Concern

(LGB&FR AOC) in northeastern Wisconsin, USA, one of the largest and most complex AOCs in the entire Great Lakes. We focus on two important BUIs: a) “degradation of fish and wildlife populations” and b) “loss of fish and wildlife habitat.” Our goal is to provide an information-rich framework that promotes cost-effective restoration efforts in this diverse ecosystem. Our emphasis is on the second stage of the RAP process (formulation of goals and recommendations for reversing the BUIs), although we also contribute to a better understanding of environmental degradation in the LGB&FR AOC and hope to provide a foundation for the final stage of the process, implementation of specific projects and management actions.

Our efforts represent a collaboration of many people from the Wisconsin Department of Natural Resources (WDNR), U.S. Environmental Protection Agency (USEPA), The Nature Conservancy (TNC), the University of Wisconsin-Green Bay, UW Sea Grant, NEW Water, members of the LGB&FR AOC Citizen’s Advisory Group, and others. We view this collaboration as a continuation of the public efforts initiated by the 1988 RAP, the first remedial action plan for a Great Lakes AOC (Wisconsin Department of Natural Resources 2016a). Updates of the original RAP were produced in 1993, 2009, and annually between 2011 and 2016. Likewise, we anticipate future updates and revisions to this document as new information comes to light and as lessons are learned from implementation of projects and management actions. Hence, this report should be viewed as a living document that coalesces active data resources, expert opinion, ongoing scientific research, and assessment metrics. The underlying goal is to create a road map for lasting improvements in the condition of fish and wildlife habitats and populations in the LGB&FR AOC.

METHODS

Overview

Work on this project officially began on 11 February 2015, when the WDNR/USEPA Award GL-00E01312 Sub 4 (“Lower Green Bay and Fox River Area of Concern Habitat Restoration Plan and Path Toward Delisting”) was officially approved by the University of Wisconsin Board of Regents. During the subsequent three years, activities can be grouped into four overlapping themes: 1) Planning Phase (August 2014-June 2015), 2) Data Gathering Phase (April 2015-September 2017), 3) Analysis Phase (October 2016-August 2017), and 4) Recommendation Phase (August 2017-December 2017). Field surveys, included in the Data Gathering Phase, were conducted during late spring and summer of all three years. Details about progress and milestones are contained in quarterly progress reports, which are archived at the UW-Green Bay Cofrin Center for Biodiversity. The primary geographic focus of this project is the area within 1 km landward of the ordinary high water mark from Long Tail Point on the west shore of Green Bay, to the De Pere Dam on the Fox River, to Point au Sable on the east shore of Green Bay (Figure 1.1).

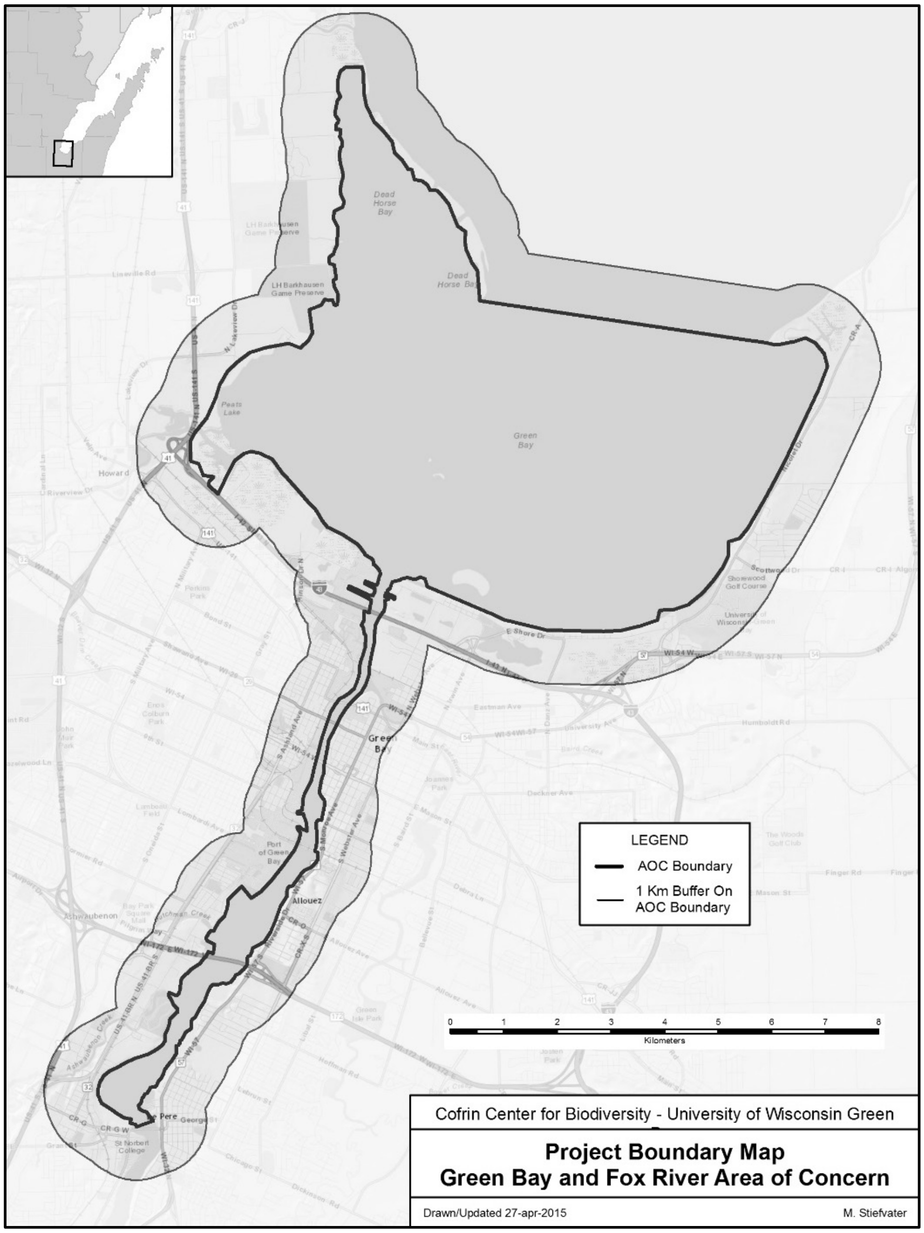


Figure 1.1. Map showing the LGB&FR AOC boundary, defined as area within 1 km of shoreline at Lake Michigan/Green Bay high water level of 177.2 m AMSL.

Two detailed Scopes of Work were completed in December 2014 (project phase 1) and June 2016 (project phase 2) and the Quality Assurance Project Plan (QAPP) was finalized in March 2016. Field surveys of anurans and birds were conducted during late spring and summer 2015 (Table 1.1; Appendices 1-1.2 and 2), following protocols developed by the Great Lakes Coastal Wetland Monitoring Program (Uzarski et al. 2017) and Knutson et al. (2008). The first of 17 meetings with technical stakeholders was held on 23 June 2015. These valuable meetings, typically attended by 25-30 natural resources professionals, provided an ongoing exchange of information and important feedback that were incorporated into the recommended BUI removal framework.

Table 1.1. Summary of appendices located at the end of this report detailing field methods for bird, anuran, and plant surveys conducted in the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC), comprehensive bibliography, and priority area narratives. Appendices with an asterisk (*) indicate projects funded under a different grant than the rest of this report.

Appendix	Title	Description
1	Bird Survey Methodology (2015-2017)	Bird surveys conducted in 2015-2017 in the LGB&FR AOC broken down by habitat type or bird group (Appendices 1.1-1.3).
1.1	Surveys in Open Wetlands (2015-2016)	Field methods for LGB&FR AOC bird surveys conducted in open wetland habitats and data processing description.
1.2	Surveys in Non-Open Wetland Habitats (2015)	Field methods for LGB&FR AOC bird surveys conducted in non-open wetland habitats (e.g., hardwood swamp, old field) and data processing description.
1.3*	Surveys of Migratory Waterfowl (2016-2017)*	Field methods for ground-based, LGB&FR AOC migratory waterfowl surveys and data processing description.
2	Anuran Survey Methodology (2015)	Field methods for LGB&FR AOC anuran (frogs + toads) surveys conducted in open wetland habitats and data processing description.
3	Habitat Mapping (2015) Methodology	Description of LGB&FR AOC field habitat mapping and data processing description.
4	Botanical Survey Methodology of Plant Biodiversity Hotspots (2016)	Field methods for finding and cataloguing terrestrial native plant biodiversity hotspots in the LGB&FR AOC and data processing description.
5*	Submerged Aquatic Vegetation Surveys (2017)*	Field methods for mapping and cataloguing submerged aquatic vegetation in the LGB&FR AOC.
6	EndNote Bibliography	Summary of LGB&FR AOC-related references and citations.
7	Mapping Historical Information for the LGB&FR AOC	Overview of mapping historical information in the LGB&FR AOC from the 1800s and 1945.
7.1	Mapping Information from the Public Land Survey System (PLSS)	Methods for geotagging 1800s PLSS surveyor locations in the LGB&FR AOC with annotated notes about vegetation, Native American tribes, etc.
7.2	Wisconsin Land Economic Inventory Maps (“Bordner Surveys”)	Methods for georeferencing the Brown County Bordner Survey, which was conducted in 1945.
8	Table Summaries of LGB&FR AOC Biota Database	Additional summary tables of the LGB&FR AOC Biota Database referenced in the Results section of this report.
9	Project Recommendations	List of recommended objectives and projects for the LGB&FR AOC and their associated impacted priority habitats and populations
10	Priority Area Narratives	Detailed narratives describing special features, significant plants and animals, habitat quality, site history, and other important aspects of the 14 highest ranked priority areas in the LGB&FR AOC (Appendices 7.1-7.14).
10.1	Fox River	Narrative of the priority area "Fox River."
10.2	Green Bay Open Water East	Narrative of the priority area "Green Bay Open Water East."
10.3	Green Bay Open Water West	Narrative of the priority area "Green Bay Open Water West."
10.4	Bay Shore Woods & Beach	Narrative of the priority area "Bay Shore Woods and Beach."
10.5	Cat Island	Narrative of the priority area "Cat Island."
10.6	Dead Horse Bay	Narrative of the priority area "Dead Horse Bay."

10.7	Duck Creek Estuary North	Narrative of the priority area "Duck Creek Estuary North."
10.8	Longtail Point	Narrative of the priority area "Longtail Point."
10.9	Malchow/Olson Tract	Narrative of the priority area "Malchow/Olson Tract."
10.10	Peters Marsh	Narrative of the priority area "Peters Marsh."
10.11	Point Sable	Narrative of the priority area "Point Sable."
10.12	Upper Duck Creek North	Narrative of the priority area "Upper Duck Creek North."

A major field habitat mapping effort covering more than 600 points throughout the LGB&FR AOC was conducted during the week of July 13-17 & 30, 2015. Eighteen pre-trained field workers participated in this work, which helped characterize the type and quality of mapped GIS habitat polygons in the LGB&FR AOC.

Under the guidance of GIS Technician Michael Stiefvater and Project Leader Erin Giese, information from the field surveys was used to create an ArcGIS shapefile of 992 polygons representing 20 habitat categories, in addition to developed and agricultural lands. This field effort produced 934 on-the-ground, digital photographs documenting these habitats, in addition to aerial images contributed by Applied Ecological Services and Bay-Lake Regional Planning Commission through their research on common reed (*Phragmites australis*; hereafter referred to as "*Phragmites*") in lower Green Bay. Modifications of these geospatial data were continued through the duration of the project. Details on this effort are covered in Appendix 3 of this report and a separate GIS technical report (available upon request).

During the summer of 2016, graduate student Ellie Roark, under the guidance of Stiefvater and Howe, conducted a systematic review of historic conditions in the LGB&FR AOC, including an analysis of 1840s Public Land Survey System notes (Appendix 7.1). Roark also georeferenced the 1945 paper map of Brown County from the Wisconsin Land Economic Inventory (aka "Bordner Surveys"; Appendix7.2). This information helped create a context for restoration efforts and the identification of priority conservation areas, which were first introduced to stakeholders and others on 17 December 2015.

Summer field work during 2016 helped fill information gaps from the initial surveys and focused on the identification of habitat "hotspots" representing remnant native plant communities (Appendix 4). Two valuable field projects, a study of Odonates by Willson Gaul and bats by Jeremiah Shrovnal, were funded during summer 2016 through independent sources. Summary technical reports of each of these studies are available upon request.

The first versions of our quantitative assessment tools were developed during the last quarter of 2016. Initially, these were created for 1) priority areas and 2) species/species groups, which each corresponded to the loss of fish and wildlife habitat BUI and the degradation of fish and wildlife populations BUI, respectively. During the summer of 2017, however, the priority areas tool was replaced by a similar analysis of habitat types. As a result, our assessment framework now provides separate analytical tools for each of the two targeted BUIs. This framework (described below) was presented in various stages to stakeholders and conservation partners between December 2016 and December 2017.

Two important supplementary field projects, one on migratory waterfowl (led by consultant Thomas Prestby) and another on submerged aquatic vegetation (SAV; led by Amy Wolf and James Horn), were completed during 2017 with funds from the WDNR. Results from these studies have been incorporated into the assessment tools and lists of recommended projects. Field methodologies are described in detail in Appendix 1.3 (migratory waterfowl) and 5 (SAV).

Throughout this project, UW-Green Bay PIs (Wolf, Howe, and Giese) met regularly with colleagues Nicole Van Helden and Mike Grimm from The Nature Conservancy, whose watershed component of this project is described in a separate section. We have integrated our respective project outcomes by extending priority areas to include refugia along the East River and Duck Creek corridors and by identifying mechanisms by which conservation in the watershed can have positive impacts on the 18 habitats and 22 species/species groups that contribute to the two fish and wildlife BUI removal targets.

Biota Database

In an effort to gather all available information pertaining to LGB&FR AOC fish and wildlife populations and habitat, we assembled annotated lists of all known and expected species of vertebrates, vascular plants, and invertebrates of conservation concern or special ecological significance found within 1 km inland of the ordinary high water mark of the LGB&FR AOC boundary. These annotated species lists were compiled and organized into an easy-to-use, searchable MS Access database documenting species presence within 1 km inland of the LGB&FR AOC.

Each record in the LGB&FR AOC Biota Database contains all relevant information pertaining to a single species (or in some cases just taxon), including scientific and common names, taxon group to which it belongs, federal and state statuses, smaller project area in which it was found (e.g., Point Sable), and data source. Seventy-five different people, organizations, universities, and agencies contributed data to the LGB&FR AOC Biota Database. In some cases, we contacted individual people requesting information or data that document species' presence in the LGB&FR AOC, which were then incorporated into the database with permission. In other instances, we compiled information from publicly available sources, such as scientific manuscripts, technical reports, websites, and books, but also received information documenting fish and wildlife populations outside of the LGB&FR AOC project (e.g., northern bay of Green Bay). These are included in the database as well in case they may be useful for future studies or comparisons.

Metadata and more details pertaining to this database are available in files "AOC_BiotaDB_Metadata_v20180429.docx" and "AOC_BiotaDB_ProjectArea&RegionSelection_20171103.docx" in the project's final data archive. Note that the smaller project areas described here are based on our earlier work using watershed boundaries, which are slightly different than "priority areas" that will be described later in this report. Metadata on this database includes maps of each of these project areas.

Historical Plant Communities

In order to identify potentially successful habitat restoration projects, we collected and summarized information on historical plant communities and significant landscape changes in the LGB&FR AOC using several sources in the Results section of this report and Appendix 10's priority area narratives:

- Article, "The vegetative pattern around Green Bay in the 1840s as related to geology, soils and land use by Indians with a detailed look at the Townships of Scott, Green Bay, and Suamico" by John Dorney (1975).

- Article, “The rooted vegetation of west Green Bay with reference to environmental change” by George Howlett (1974).
- Website for the La Baye Indian and Métis Community Project, directed by Lynn Austin, provided historical maps (http://www.labaye.org/).
    - For example, 1845 map of the head of lower Green Bay, Wisconsin: http://s3.amazonaws.com/labaye/data/1845%20Head%20Of%20Green%20Bay.pdf
- Multiple meetings with Thomas Erdman, retired Curator to the UW-Green Bay Richter Museum, who is also a local historian of the lower Green Bay area with extensive historical knowledge about this landscape, plant communities, birds, and other wildlife.
- Coastal Bordner Project, co-led by the UW-Madison Forest Ecosystem and Landscape Ecology Lab and the State Cartographer's Office. They converted the Wisconsin Land Economic Inventory, aka “Bordner Surveys,” which mapped the state of Wisconsin according to land use/land cover types in the 1920s-1940s, into GIS geodatabases available for free online. Brown County was surveyed in 1945.
    - Project website: https://maps.sco.wisc.edu/BordnerCoastal/about/#About
    - GIS portal to view the Bordner Surveys land use/land cover data online: https://maps.sco.wisc.edu/BordnerCoastal/?featureType=polygons&basemap=streets
- UW-Green Bay graduate student, Ellie Roark, georeferenced the original Bordner Survey map of Brown County into ArcGIS (Appendix 7.2).
- Original 1800s Public Land Survey System (PLSS) land cover information:
    - The WDNR’s online Surface Water Data Viewer provides a GIS layer of the original historical vegetation of Wisconsin.
- Roark geotagged 1840s PLSS surveyor locations in the LGB&FR AOC with annotated notes about vegetation, Native American tribes, etc. The geotagged notes from these locations extend beyond the land cover type provided in the WDNR’s GIS data layer because they provide more location-specific details such as nearby trees growing, Native American campsites, wild rice beds, housing, etc. (Appendix 7.1).
- Article, “The Green Bay Watershed: Past/Present/Future” by Gerard Bertrand et al. (1976).
- Article, “Loss of wetlands on the west shore of Green Bay” by T.R. Bosley (1978).
- Article, “Vegetation change in Great Lakes coastal wetlands: deviation from the historical cycle” by Christin Frieswyk and Joy Zedler (2007).

Even though the lower Green Bay ecosystem has undergone significant and in many cases permanent land cover changes (e.g., roads, housing), having a better understanding of the locations of dominant historical plant communities in the LGB&FR AOC helps guide current and future restoration efforts. This is especially true for knowing where desirable plants, such as wild rice, used to grow in the lower bay.

Critical Biotic and Abiotic Elements of the AOC

Information from the Biota Database and historical analysis of plant communities provided a foundation for selecting a manageable list of conservation targets in the LGB&FR AOC. The two BUIs (loss of fish and wildlife habitat and degradation of fish and wildlife populations) are complementary and lead to a comprehensive array of specific biotic and abiotic elements that need to be addressed in order to justify BUI removal.

Habitats act as coarse filters. Protecting or restoring quality natural habitats in the LGB&FR AOC will benefit many species that are dependent on those habitats. Some of the habitat-associated species are conspicuous and well known, but many beneficiaries of habitat conservation are invertebrates, microorganisms, and inconspicuous or poorly studied vertebrates that have no conservation status. By protecting or restoring habitat, however, these cryptic species simultaneously benefit.

Individual species or species groups (e.g., nearshore fishes, coastal wetland breeding birds) represent a finer-scale filter, which directs conservation efforts to biotic elements that are not necessarily covered by habitat protection or restoration. These might be species or species groups that require multiple habitats, or species that are rare or uncommon and are not always present in a tract of favored habitat.

We identified all major habitats present in the LGB&FR AOC following the natural community classification system developed by the Wisconsin Department of Natural Resources (2015). The natural community definitions were modified slightly to provide more detailed descriptions of several habitats, leading to a list of 18 habitat categories (Table 1.2), which were listed as important in the original RAP (Tables 1.4 and 1.5). One of the most important natural communities, “emergent marsh,” for example, was split into four different categories to differentiate the influence of the bay on habitat dynamics and to separate fundamentally different fish and wildlife species assemblages. “Emergent marsh (high energy coastal)” describes wetlands that are exposed directly to wave action from Green Bay. Two other types, “emergent marsh (riparian)” and “emergent marsh (inland),” occur along rivers and inland basins, respectively. The category “emergent marsh (roadside)” includes all other small, mostly linear wetlands associated with roads and developed lands. We formulated a description of each habitat type, along with an estimate of its overall condition in the LGB&FR AOC. This information helped us set specific habitat-based conservation targets and functional “condition curves” that can be used to track progress toward these targets.

Table 1.2. List of Lower Green Bay and Fox River AOC fish and wildlife habitats, including five weighting criteria (scale: 0 = none, 1 = low, 2 = medium, and 3 = high), which produce composite habitat weights (sum of 5 scores). Baseline condition estimates (Cond.) range from 0 = worst possible condition to 10 = best possible condition. Values for AOC conservation status: 1 = S4 status (apparently secure in WI), 2 = S3 status (vulnerable in WI) or connected open water, tributaries, river, etc., and 3 = S2 status (imperiled in WI). Geographic significance describes connectivity to Green Bay or Fox River: 1 = low (inland), 1.5 = low-medium (lowland), 2 = medium (areas along tributaries), and 3 = high (pelagic zone, Fox River, islands, peninsulas, etc.). Superscripts listed after each habitat type are links to Tables 1.4 and 1.5. Based on consensus of local experts, the overall current condition of the "loss of fish and wildlife habitat" BUI in the Lower Green Bay and Fox River AOC is 3.60.

Priority Habitat	Historical Importance	AOC Conservation Status	Geographic Significance	Significance to AOC Biodiversity	Functional Significance	Weight	Condition
Great Lakes Beach[a]	3	3	3	3	2	14	2
Southern Sedge Meadow[b]	3	2	3	3	3	14	2
Emergent Marsh (high energy coastal)[c]	3	1	3	3	3	13	4
Submergent Marsh[d]	3	1	3	3	3	13	5
Emergent Marsh (riparian)[c]	3	1	2	3	3	12	3
Fox River Open Water[e]	3	2	3	2	2	12	3
Green Bay Open Water[f]	3	2	3	2	2	12	3
Shrub Carr[g]	3	1	2	3	3	12	4
Tributary Open Water[h]	3	2	3	2	2	12	3
Hardwood Swamp[i]	3	2	1.5	2	3	11.5	5
Emergent Marsh (inland)[c]	2	1	1	2	3	9	4
Open Water (inland)[j]	2	1	1	1	2	7	3
Southern Dry Mesic Forest[k]	1	2	1	1	2	7	5
Emergent Marsh (roadside)[c]	0	1	2	2	1	6	3
Northern Mesic Forest[l]	1	1	1	1	2	6	4
Other Forest[m]	1	1	1	1	1	5	5
Surrogate Grassland (old field)[n]	1	1	1	1	1	5	5
Surrogate Grassland Restored[o]	1	1	1	1	1	5	5
						Current Condition	**3.60**

Our list of priority species and species groups encompasses all official federal and state-listed animal species recorded from the study area, other species that have been described by published studies as sensitive to human disturbance (e.g., Brazner 1997), and several ecologically important "keystone" species (Paine 1969, Mills et al. 1993, Valls et al. 2015) present in the study area. We also tried to include all wildlife species that were mentioned in previous LGB&FR AOC strategic plans and sensitive species that are ecologically or economically important and amenable to cost-effective monitoring. Twelve animal species that regularly occur in the LGB&FR AOC as breeders or migrants are listed as endangered or threatened by government agencies, including the federally endangered Piping Plover (*Charadrius melodus*), federally threatened Red Knot (*Calidris canutus*), and recently federally listed rusty-patched bumble bee (*Bombus affinis*). Another 50 species are listed in Wisconsin as state special concern, and at least 11 others are identified as conservation priorities by one or more non-profit conservation organizations. We added 51 animal taxa that have been shown to be sensitive to human disturbance according to published studies or data from the Great Lakes Coastal Wetland Monitoring Program (Uzarski et al. 2017). Muskrat (*Ondatra zibethicus*) is considered by many to be a keystone species (Paine 1969) and was mentioned by earlier versions of the LGB&FR AOC RAP, so we also added it to the list, yielding a grand total of 125 priority species or taxonomic groups. This number omits many poorly studied invertebrate taxa, including locally extirpated species like mayfly (*Hexagenia bilineata*; Cochran 1992) and freshwater mollusks in the families Unionidae and Sphaeriidae (Howmiller and Beeton 1971).

We combined ecologically similar species into functional species groups and identified other taxonomic groups that have been recognized as important elements of the lower Green Bay and Fox River ecosystem. Examples of these multi-species groups include “colonial breeding waterbirds,” “tributary fish,” and “coastal wetland aquatic macroinvertebrates.” A few species of special interest or importance (Piping Plover, muskrat, wintering Bald Eagles [*Haliaeetus leucocephalus*]) could not be easily assigned to our initial groups and were listed uniquely. Nearly all species in the priority list and virtually all wildlife taxa identified by previous RAPs for this AOC are included in one of the wildlife species groups (Tables 1.4 and 1.5), which were developed with substantial input from local experts and stakeholders. Our final list of species/species groups consisted of 22 taxa (Table 1.3). Like the 18 priority habitats, the 22 species/species groups are summarized in individual narrative accounts, accompanied by condition curves that identify current condition as well as the ideal condition that can be attained with conservation actions.

Table 1.3. Lower Green Bay and Fox River AOC priority fish and wildlife species/species groups, with six weighting criteria (1 = low, 2 = medium, and 3 = high), producing composite species/species group weights (sum of 5 scores). Current condition estimates range from 0 = worst possible condition to 10 = best possible condition. Conservation status: 1 = no status, 2 = some status (e.g., Special Concern), and 3 = high status (e.g., Endangered). Condition scores, based on consensus of local experts, are combined with weights to yield a composite condition of 4.65 for the "degradation of fish and wildlife populations" BUI. Numerical superscripts listed after each species/species group are references for Tables 1.4 and 1.5.

Priority Species or Species Groups	Toxic Sensitivity	Economic Importance	Aquatic Dependent	Keystone Species	Conservation Status	Impact Potential	Weight	Cond.
Colonial waterbirds (breeding)[1]	3	2	3	2	3	3	16	5
Coastal wetland mustelids[2]	3	3	3	2	1	3	15	4
Tributary fish[3]	2	3	3	2	2	3	15	5
Coastal birds (breeding)[4]	3	2	3	1	3	2	14	6
Fox River fish[5]	3	3	3	2	1	2	14	5
Freshwater unionid mussels[6]	3	1	3	1	3	3	14	1
Shoreline fish[7]	2	3	3	2	1	3	14	4
Wetland terns[8]	3	2	3	1	3	2	14	3
Muskrat[9]	1	2	3	3	1	3	13	6
Piping Plover[10]	2	3	2	1	3	2	13	2
Anurans[11]	2	1	3	1	2	3	12	7
Bald Eagle (winter)[12]	3	2	2	1	2	2	12	7
Marsh breeding birds[13]	2	2	3	1	2	2	12	6
Coastal terrestrial macroinverts[14]	1	1	3	2	2	3	12	3
Shorebirds (migratory)[15]	2	2	3	1	2	2	12	5
Waterfowl (migratory)[16]	2	3	3	1	1	2	12	6
Bats[17]	2	1	1	1	3	3	11	4
Coastal wetland aquatic macroinverts[18]	1	1	3	2	1	3	11	3
Stream macroinverts[19]	1	1	3	2	1	2	10	4
Turtles[20]	2	1	3	1	1	2	10	5
Wooded wetland birds (breeding)[21]	1	2	2	1	1	2	9	6
Landbirds (migratory)[22]	1	2	1	1	1	2	8	7

Current Condition **4.65**

Table 1.4. Crosswalk between the 2011 Lower Green Bay and Fox River Area of Concern Remedial Action Plan targets for fish and wildlife habitats (Wisconsin Department of Natural Resources, 2016) and elements of the fish and wildlife species/species groups (1-22; Table 1.3) and habitat types (a-o; Table 1.2).

Fish & Wildlife Habitat Target	Assessment Tool Reference
Fish and wildlife management goals are achievable as a result of the physical, chemical, and biological integrity of the AOC waters, including wetlands.	b-f, h-j; all populations
A balance of diverse habitat types exists within the AOC that supports all life stage requirements of fish and wildlife populations including:	all habitats + populations
1. Multiple wetland types (for example: submerged aquatic vegetation, emergent vegetation, sedge meadows, forested & shrub) that adequately represent historic wetland types	b-d, g, i
2. Quality fish spawning habitats	a, c-f, h, j; 3, 5, 7
3. Islands for colonial nesting birds, amphibians, and furbearers	a, c, d; 1, 2, 9, 11
4. Intact migration corridors (both shoreline and water)	a, c, e, f, h
5. Unconsolidated beaches (for shorebirds)	a; 10, 15
6. Habitat for State or Federally listed species (special concern, threatened, or endangered)	a-j; 1, 3, 4, 5, 6, 8, 10-13, 15-17, 20, 22
The hydrologic connectivity between wetlands and the AOC is maintained and restored sufficiently to support fish spawning and allow for fish passage.	c-f, h, j; 3, 5, 7
The Green Bay portion of the AOC contains water clarity and other conditions suitable for support of a diverse biological community, including a robust and sustainable area of submersed aquatic vegetation in shallow water areas.	d, f
The AOC contains a diversity of plants, an abundance of submersed aquatic vegetation, and sufficient invertebrates to provide adequate food supplies to support a diverse assemblage of migratory diving ducks (both mussel and vegetation feeding), fish, and other wildlife (including aquatic invertebrates, amphibians, and reptiles).	all habitats; 3, 5-7, 11, 14, 16, 18-20
The AOC meets water quality standards and/or water quality targets of a State and US EPA approved TMDL. The approved TMDL targets are summer median concentrations of 0.10 mg/L TP and 20 mg/L TSS at the mouth of the river.	e, f, h
The AOC meets Wisconsin water quality criteria for dissolved oxygen and water temperature that are protective of fish and wildlife populations.	e, f, h
No waterbodies within the AOC are listed as impaired due to physical or water chemistry conditions in the most recent Wisconsin Impaired Waters List (303(d) List).	e, f, h, j

Table 1.5. Crosswalk between the 2011 Lower Green Bay and Fox River Area of Concern Remedial Action Plan targets for fish and wildlife populations (Wisconsin Department of Natural Resources, 2016) and elements of the fish and wildlife species/species groups (1-22; Table 1.3) and habitat types (a-o; Table 1.2).

Fish & Wildlife Populations Target	Assessment Tool Reference
The AOC contains healthy, self-sustaining, naturally reproducing, and diverse populations of native fish species (including walleye, northern pike, yellow perch, lake sturgeon, Great Lakes spotted muskellunge, and centrarchids) in abundances sufficient to provide ecological function in the fish community	3, 5, 7
Populations of traditionally harvested fish species are capable of supporting some level of exploitation	3, 5, 7
The AOC contains healthy, self-sustaining, naturally reproducing, and diverse populations of native furbearers (including mink, muskrats, and otter), amphibians (including spring peepers, leopard frogs, American toads, eastern gray tree frogs, green frogs, bullfrogs, and salamanders), reptiles (including snapping and painted turtles), terns (common and Forster's), migratory diving ducks, dabbling ducks, marsh nesting birds and island-dependent colonial nesting birds in abundances sufficient to provide ecological function	1, 2, 8, 9, 11, 13, 16, 20
Populations of traditionally harvested wildlife species are capable of supporting some level of exploitation	2, 3, 5, 7, 9, 11, 13, 16, 21
Invasive species (lamprey, carp, gobies, white perch, and others) expansion is minimized and controlled as needed to protect native species within the AOC and upstream	3, 5, 7
Contaminant levels in forage fish populations do not impair the reproductive success of fish-eating birds and wildlife (including predatory fish) and meet the criteria established in Annex 1 of the 1978 Great Lakes Water Quality Agreement as amended by Protocol in 1987, specifically "the concentration of total polychlorinated biphenyls in fish tissues (whole fish, calculated on a wet weight basis), should not exceed 0.1 micrograms per gram for the protection of birds and animals which consume fish"	1-5, 7-9, 12, 20
The AOC supports fish and wildlife populations at levels consistent with extant fish and wildlife management plan objectives. Specifically, the following objectives should be met unless extant management plans have updated criteria (specific objectives identified in past RAP documents are listed in Appendix B of the 2015 RAP update)	all populations

Conservation Project Catalogue

In an effort to identify all fish and wildlife projects occurring in the LGB&FR AOC, we created a catalogue of current and historical conservation projects, including environmental monitoring programs, restoration projects, land use planning, and other conservation activities. These projects were compiled and organized into a MS Excel database. Knowing what work different agencies, non-profit organizations, tribes, universities, cities/towns, environmental consulting/engineering firms, and others are doing in the LGB&FR AOC provides a foundation for future project planning.

Each record in the LGB&FR AOC Conservation Project Catalogue contains all available, relevant information pertaining to that project, including project or program title, objective, focus (e.g., restoration, monitoring, plan), what taxon or taxa were studied, restored, or focused on, start/end dates, leader(s), funding source(s), general location, and contact information. If data were available, most projects were also geospatially referenced into an ArcGIS shapefile. In some cases, we contacted individual people requesting information on projects that have taken place or are currently taking place in the LGB&FR AOC, which were then incorporated into the database. In other instances, the UW-Green Bay team compiled information from publicly available sources, such as scientific manuscripts, technical reports, websites, and books, or compiled information that was presented at a meeting organized by the UW-Green Bay team (e.g., June 2015 stakeholder meeting) or elsewhere (e.g., Green Bay Conservation Partners annual meetings). In a few cases, we received information documenting projects outside of the LGB&FR AOC project (e.g., northern bay of Green Bay, watershed). These were included in the database as well in case they may be useful for future studies. One potential (but not currently funded) project was also documented in this database.

Stakeholder Engagement

Throughout the project, we engaged stakeholders representing agencies (e.g., Wisconsin Department of Natural Resources, U.S. Fish and Wildlife Service), non-profit organizations (e.g., The Nature Conservancy), retired local experts, and many other organizations (e.g., Bay-Lake Regional Planning Commission) using a variety of ways. At times we presented various aspects of the project in a presentation-style setting but did not seek feedback. In other cases, we organized interactive meetings, in which we sought specific feedback for particular aspects of the project.

Fish & Wildlife Assessment + BUI Removal Process

The LGB&FR AOC consists of many habitats, which in turn support many fish and wildlife species. Setting meaningful restoration targets in such a complex ecosystem is challenging, complicated further by the dynamic nature of the Great Lakes coastal environment (De Stasio Jr. and Richman 1998, O'Donnell et al. 2013). Our strategy for setting conservation goals in the LGB&FR AOC involved six general steps, producing a roadmap with multiple pathways for successful remediation of each BUI:

*1. Identify the specific environmental features that have been impaired in the LGB&FR AOC, in this case **habitats** and important **species/species groups**.*

This initial step required a comprehensive review of historical information, including original land survey notes, published scientific articles, historical air photos, data from archived biological surveys, and reports from government agencies. We augmented these resources with our own field surveys conducted during 2015, 2016, and 2017 to update information about the status and distribution of important habitats and species. The field work was not comprehensive but combined with results from published studies and historical observations, we were able to compile a rich digital database representing the prominent flora, fauna, and natural communities of the LGB&FR AOC. All of the 18 priority habitats and 22 priority species/species groups identified as “Critical Biotic and Abiotic Elements of the AOC” were included in this analysis.

*2. Quantify the relative importance of these habitats and species/species groups based on objective ecological and socioeconomic criteria. Results provide quantitative **weightings** for each habitat and species/species group.*

Habitats and species in any area differ in their ecological and socioeconomic importance. In order to focus restoration on targets with the highest benefit/cost ratio, we developed a systematic ranking system to establish priorities among habitats and species/species groups. For each fish and wildlife habitat (Table 1.2), we applied five criteria: 1) historical importance in the LGB&FR AOC study area, 2) LGB&FR AOC conservation status (based on state and federal listings), 3) geographic significance in the LGB&FR AOC (association with the Green Bay aquatic ecosystem; e.g., pelagic zone vs. inland), 4) significance to LGB&FR AOC biodiversity, and 5) functional significance/ecological services (e.g., flood abatement). Values for each category (0, 1, 1.5, 2, or 3, where 0 = none, 1 = low value, 2 = moderate value, and 3 = high or optimal value) were summed to yield an overall priority weight for each species or species group. Note that all habitats originally identified in the 2011 RAP update are included in our list (Tables 1.4 and 1.5; Wisconsin Department of Natural Resources 2016a).

A similar process was used to prioritize species/species groups (Table 1.3). In this case, we applied six criteria: 1) sensitivity to toxic environmental chemicals, 2) economic importance, 3) dependence on aquatic or wetland environments, 4) keystone species status (i.e., importance to other species in an ecosystem), 5) conservation status (federal, state, or regional), and 6) potential impact of local restoration efforts on overall species/species groups. Again, we attempted to address all species/species groups identified in the 2011 RAP for the fish and wildlife population BUI (Tables 1.4 and 1.5; Wisconsin Department of Natural Resources 2016a).

3. Devise and apply a numerical method for measuring current or future condition of each habitat and species/species group. Convert these raw metrics to a standardized ***condition score*** *ranging from 0 (worst case) to 10 (best case).*

We enlisted the help of regional biologists and other experts, combined with the information that we acquired from field surveys and historical analysis, to assign **baseline condition** values for all 18 habitats and 22 species/species groups. These scores establish reference points from which changes in condition can be tracked. In all cases, the assigned values were relative not to the best possible condition but to the best attainable condition (10) given irreparable constraints (e.g., urban development) present in the LGB&FR AOC today. The baseline scores can be modified in light of new information, but for now they provide a necessary starting point.

Condition scores vary as habitats and species/species groups change for better or worse. Changes in condition are tracked by one of three general types of metrics based on quantitative field methods: 1) Direct measurements (e.g., number of Piping Plover nests) are converted directly to the 0-10 scale by a conversion curve, which might be linear or nonlinear. 2) Rubric metrics combine two or more attributes on a ranked scale, converted to values ranging from 0-10. This is the most common type of metric for habitat scores, where a GIS-generated quantity like number of hectares is modified by the quality of habitat at different sites. For example, a 10-ha patch of poor-quality habitat is weighted by a factor <1.0 so that the patch is not equivalent to a 10-ha patch of high quality habitat. The weighting factor (0-1) should be clearly documented by criteria, such as those described in Tables 1.2 and 1.3. Other types of rubric metrics might establish a graduated scale of increasing ecological robustness. For example, the documented presence of one species of turtle in the AOC would yield a non-zero but low score for a rubric-based turtle metric; the documented successful breeding of that one species would produce a moderate score, while the documented successful breeding of three turtle species would yield an even higher score. The various levels of success or quality must be articulated in a rubric to guide the assignment of scores. 3) Multispecies metrics combine information from entire species assemblages or biotic samples. The index of ecological condition or (IEC; Howe et al. 2007, Gnass Giese et al. 2015) and index of biotic integrity (IBI; Karr 1981, Uzarski et al. 2017) represent two useful approaches for developing multispecies indices. In both cases, the metrics should be customized for local application to avoid biogeographic bias (Herman and Nejadhashemi 2015). IBIs, like direct measurements and rubric metrics, may need to be converted to the standard 0-10 quantitative scale. IECs are already scaled from 0-10 so conversion curves aren't necessary.

Metrics for each habitat and species/species group are meant to be as simple and easily quantified as possible. For example, metrics for habitat types typically involve a quantity that can be derived from aerial imagery, like the total area of emergent coastal wetland or the total length of undeveloped Great Lakes beach, adjusted by field assessment of habitat quality. The total area or linear distance in the conversion curve (e.g., Figure 1.2) assumes that each unit area or linear distance represents a high-quality example of the habitat. One hectare of high quality coastal emergent wetland, of course, is not equivalent to one hectare that is heavily invaded by the non-native common reed (*Phragmites australis*) and hybrid cattail (*Typha × glauca*), so the units of measurement (e.g., acres/hectares) must be adjusted by a fraction corresponding to degradation in quality. A badly degraded emergent wetland area of 20 ha might contribute the equivalent of only 10 ha of high-quality wetland (20 x 0.5) because the effective area is reduced by a degradation factor of 0.5. In the case of open water habitats, the total area is fixed, so the degradation factor becomes the only variable that determines current condition.

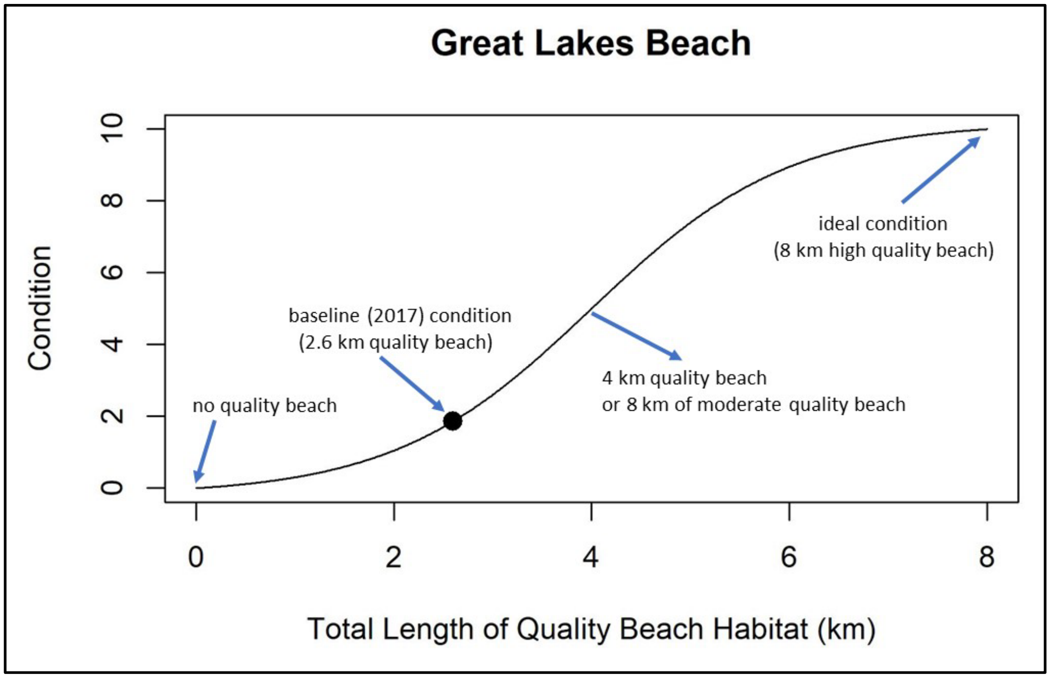


Figure 1.2. Great Lakes beach habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total length of quality beach habitat (scaled from 0 [no quality beach] to 10 [ideal beach, 8 km of high quality beach]), which is determined through field surveys, and the y-axis is the converted condition for a given length of quality beach habitat, which ranges from poor condition (0) to good/ideal condition (10).

*4. Pair the weightings with the corresponding standardized condition scores for all habitats and species/species groups. Calculate a **weighted average** of these combinations to produce a comprehensive condition metric, again ranging from 0 (worst case) to 10 (best case), for each of the two BUIs.*

The overall AOC condition for each BUI is calculated as the weighted average of condition among all biotic elements (habitats or species/species groups):

$$C_{\mathrm{BUI}} = \frac{\sum_{i=1}^{n} w_i * c_i}{\sum_{i=1}^{n} w_i} \qquad (1)$$

where C_{BUI} is the overall AOC condition of a given BUI, w_i is the priority weighting assigned to element i, c_i is the current condition of element i, and n is the total number of elements (habitats or species/species groups) used in the calculation. In our analyses, $n = 18$ habitat elements (Table 1.2) and $n = 22$ species/species groups (Table 1.3).

*5. Set a meaningful and achievable **conservation target** for each weighted BUI condition metric. This target becomes the condition (on the 0-10 scale) that justifies BUI removal of an AOC.*

A subtly important step in our framework is transforming the condition scores to a standard 0-10 scale. This same point applies to our overall assessment of condition for the two BUIs. In all cases, we define a score of 10 as the best possible biotic or ecological condition given environmental circumstances at the beginning of the assessment period (e.g., when the AOC was first designated). In other words, a 10 is not the pristine historical condition that is no longer attainable because of permanent deforestation, agricultural impacts on soils, urban development, global extinctions, or other irreversible environmental changes. Instead, a 10 represents an achievable condition given realistic ecological restoration and rehabilitation measures. Our overall target condition scores for each BUI were formulated with advice from local wildlife biologists, naturalists, scientific researchers, policymakers, and other experts during regular (at least bi-annual) "stakeholder" meetings. Even with this valuable input, we recognize that information gaps and uncertainties are inherent in this assessment framework. Hence, we view the conservation targets recommended here (like condition scores for individual habitats and species groups) as part of an adaptive management process, subject to revision and improvements as better information becomes available.

The first specific BUI removal targets for the LGB&FR AOC were articulated in the 1988 RAP and subsequent updates (Wisconsin Department of Natural Resources 2016a). Our recommended BUI removal targets build on these previous RAP targets with improved quantitative and comprehensive metrics for assessing the AOC condition of fish and wildlife habitats and fish and wildlife populations. We have incorporated the previous targets plus more in our habitat-specific (Table 1.2) and population-specific (Table 1.3) assessment tools. If our quantitative BUI targets are reached, then one can argue strongly that all of the earlier qualitative targets likewise will have been reached. One possible exception is the target aimed at minimizing levels of contaminants (particularly total polychlorinated biphenyls) in fish tissues (Wisconsin Department of Natural Resources 2016a). Even though environmental contaminants are explicitly part of other BUIs in the LGB&FR AOC, they are mentioned in the fish and wildlife population BUI because of their importance for fish populations, fish-eating birds, and other wildlife. Our framework includes no specific monitoring or assessment of toxic contaminants. We have, however, included sensitivity to toxins as one of our weighting criteria for species and species groups, leading to elevated priority weights for seven groups of fish-eating wildlife (colonial waterbirds, coastal wetland mustelids, breeding coastal birds, Fox River fish, freshwater unionid mussels, wetland terns, and wintering Bald Eagles). The 1991 BUI removal guidelines (International Joint Commission 1991) state that wildlife bioassays are needed to confirm no significant toxicity "in the absence of community structure data." We argue that our framework includes community structure data, so the bioassays are not needed as direct quantitative targets for these two fish and wildlife BUIs. This argument is strengthened by the fact that three other

BUIs in the LGB&FR AOC (Wisconsin Department of Natural Resources 2016a) deal directly with toxic contaminants: 1) fish tumors or other deformities, 2) bird or animal deformities or reproductive problems, and 3) restrictions on fish and wildlife consumption.

*6. Identify potential **management actions** and **restoration projects** that will produce cost-effective progress toward the quantitative conservation targets for fish and wildlife habitats and fish and wildlife populations, respectively.*

The last step in our BUI removal strategy is the identification of projects and management actions that will improve the condition of one or more habitats or species/species groups (and, consequently, the overall BUI condition score). Indeed, the ultimate purpose of our assessment framework (steps 1-5) is to help illuminate conservation measures that will produce the "biggest bang for the buck" in terms of removing these BUIs. Clearly, the most cost-effective actions will be those that have the strongest effect on the highest ranked habitats or species/species groups. We provide a preliminary list of recommended projects based on information that we have acquired in our Discussion section. In some cases, these actions consist of typical habitat management projects such as control of invasive *Phragmites*, acquisition of remnant natural areas, construction of artificial reefs for breeding fish habitat, or active translocation of locally extirpated species. In other cases, however, significant improvement in condition can occur through relatively inexpensive measures like conservation easements at critical private lands, revised management plans on public lands, or designation of local sensitive areas like turtle nesting sites, mussel beds, or fish spawning habitats. Our list is intended to stimulate other project recommendations by conservation agencies, citizen groups, academic researchers, and others who are familiar with local habitats and fish and wildlife populations in the LGB&FR AOC. Updated information about the status of habitats and species/species groups will objectively track progress toward the overall BUI removal targets.

The Nature Conservancy's (TNC) Watershed Assessment Tool contributes to this step in this framework. In some cases, conservation measures will be effective outside the official LGB&FR AOC boundary and our 1 km coastal zone (e.g., Duck Creek, East River). Examples include upstream spawning habitat for northern pike (*Esox lucius*), riparian refugia of rare habitats like southern sedge meadows, or upstream mussel beds, which might be important sources of recolonization in lower Green Bay. A description of TNC's methods and applications is included separately in this report in Part 2.

Priority Areas

Our focus on priority species/species groups and habitats inevitably leads to recommendations for specific conservation actions at specific places. Certain critical localities in the LGB&FR AOC have multiple habitats and species/species groups that can be protected, managed, or restored together. Hence, we described a portfolio of priority areas that ultimately will be instrumental in achieving the BUI removal targets for fish and wildlife habitats and populations. Projects conducted in these strategic areas will be particularly effective in improving the condition of priority fish and wildlife habitats and populations. We define "priority areas" as areas of importance that contain valuable fish and wildlife habitats and that may serve as convenient management units or focus areas for restoration planning. Most of these priority areas are well known and many are already under some form of public or conservation ownership. Selection criteria for the priority areas required that they: 1) consist of adequately large, relatively intact area of fish and wildlife habitat and 2) are beneficial to multiple priority species or natural community types.

We established a weighting system to rank the priority areas in order of their impact on LGB&FR AOC's fish and wildlife BUI removal targets. Improvements made to priority areas with higher weights will have a greater effect on the overall condition of fish and wildlife habitats and populations. We strongly recommend conservation management actions in these high-quality priority areas because they excel in one or more of these ecological attributes (Table 1.6, Figures 1.3-1.5):

- Area
    - *Purpose*: To distinguish small from large "priority areas."
    - *Ranks*: 1 = <25 ha, 2 = 25-49 ha, 2.5 = 50-75 ha, and 3 = >75 ha.

- Connectivity
    - *Purpose*: To determine if a "priority area" is connected to other adjacent habitats and/or ecological complexes.
    - *Ranks*: 1 = low, 2 = medium, and 3 = high.

- Presence of Rare Habitats
    - *Purpose*: To identify rare habitats within the LGB&FR AOC and/or within the state that were more common historically but should be present today. Habitats considered as rare were Great Lakes beach and southern sedge meadow.
    - *Ranks*: 1 = has no rare habitat, 2 = has some amount of rare habitat, and 3 = has significant amount of rare habitat.

- Stewardship
    - *Purpose*: To distinguish different types of land ownership and stewardship (e.g., if "priority area" has a conservation plan).
    - *Ranks*: 1 = private with no conservation plan, 2 = mixed ownership or public with no conservation plan, 3 = private and/or public with some conservation plan, and 4 = private and/or public area protected with strong conservation plan.

- Geographic Significance
    - *Purpose*: To distinguish where "priority areas" are located within the LGB&FR AOC, giving higher weight to areas located in the pelagic zone or along the shoreline since the official LGB&FR AOC boundary traces the coastal zone of the bay of Green Bay.
    - *Ranks*: 1 = low (inland areas), 2 = medium (areas along tributaries), and 3 = high (pelagic zone, Fox River open water, islands, peninsulas, significant coastal presence).

- Plant Biodiversity Hotspots
    - *Purpose*: To identify "priority areas" that contain high native plant diversity.
    - *Ranks*: 1 = low, 2 = medium, and 3 = high.
    - Note that James Horn and two UW-Green Bay students visited and catalogued terrestrial native plant biodiversity hotspots at many of the higher quality "priority areas," which helped us populate this field (Appendix 4).

Table 1.6. Twenty-nine “priority areas” and their respective weightings (2, 3, 4, or 5), six selection criteria (e.g., Area Rank, Geographic Significance) that range from 1 to 3, and “priority scores” (sum of each of the six selection criteria). Despite slightly lower priority scores, Green Bay Open Water East, Green Bay Open Water West, and Fox River were assigned weights of 5 since they constitute the official Lower Green Bay and Fox River Area of Concern (LGB&FR AOC) boundary. Improvements conducted on higher weighted “priority areas” will have a larger impact on the overall condition of fish and wildlife habitats and populations in the LGB&FR AOC.

Priority Area	Weight	Area (ha)	Area Rank	Connectivity	Presence of Rare Habitats	Stewardship	Geographic Significance	Plant Biodiversity Hotspots	Priority Score
Green Bay Open Water East	5	3207.1	3	3	1	2	3	2	14
Green Bay Open Water West	5	2165.1	3	3	1	2	3	2	14
Fox River	5	526.3	3	3	1	2	3	2	14
Long Tail Point	4	130.2	3	3	3	3	3	2	17
Point Sable	4	106.4	3	2	3	3	3	3	17
Dead Horse Bay	4	167.8	3	3	1	3	3	3	16
Cat Island	4	152.5	3	3	3	3	3	1	16
Malchow/Olson Tract	4	139.0	3	3	3	1	3	3	16
Duck Creek Estuary North	4	82.5	3	3	1	3	3	3	16
Peters Marsh	4	106.6	3	3	1	3	3	1	14
Upper Duck Creek North	4	85.3	3	2	1	3	2	3	14
Bay Shore Woods and Beach	4	18.6	1	2	3	3	3	2	14
East River	4	253.2	3	3	1	2	3	2	14
Duck Creek	4	82.3	3	3	2	2	2	2	14
Sensiba South	3	59.9	2.5	3	1	2	3	2	13.5
Frying Pan Shoal / Point Sable Bar	3	763.8	3	3	1	2	3	1	13
Duck Creek Estuary South	3	80.1	3	3	1	2	3	1	13
Mahon Woods and Creek	3	27.4	2	2	2	3	2	2	13
Lone Tree & Grassy Island	3	0.3	1	3	2	3	3	1	13
Ken Euers Nature Area	3	56.5	2.5	3	1	2	3	1	12.5
Barkhausen Waterfowl Preserve	3	53.0	2.5	3	1	3	1	2	12.5
Fort Howard Wildlife Area	2	98.4	3	3	1	3	1	1	12
Fox River Mouth	2	29.2	2	3	1	2	3	1	12
Long Tail Beach Road Hardwood Swamp	2	73.0	2.5	3	1	2	1	2	11.5
Bay Beach Wildlife Sanctuary East	2	126.2	3	2	1	3	1	1	11
Bay Beach Wildlife Sanctuary West	2	113.7	3	2	1	3	1	1	11
Cottage Grove Complex	2	44.9	2	3	1	1	3	1	11
Upper Duck Creek South	2	22.5	2	2	1	2	2	2	11
Bay Beach Amusement Park Shoreline	2	15.1	1	1	3	2	3	1	11

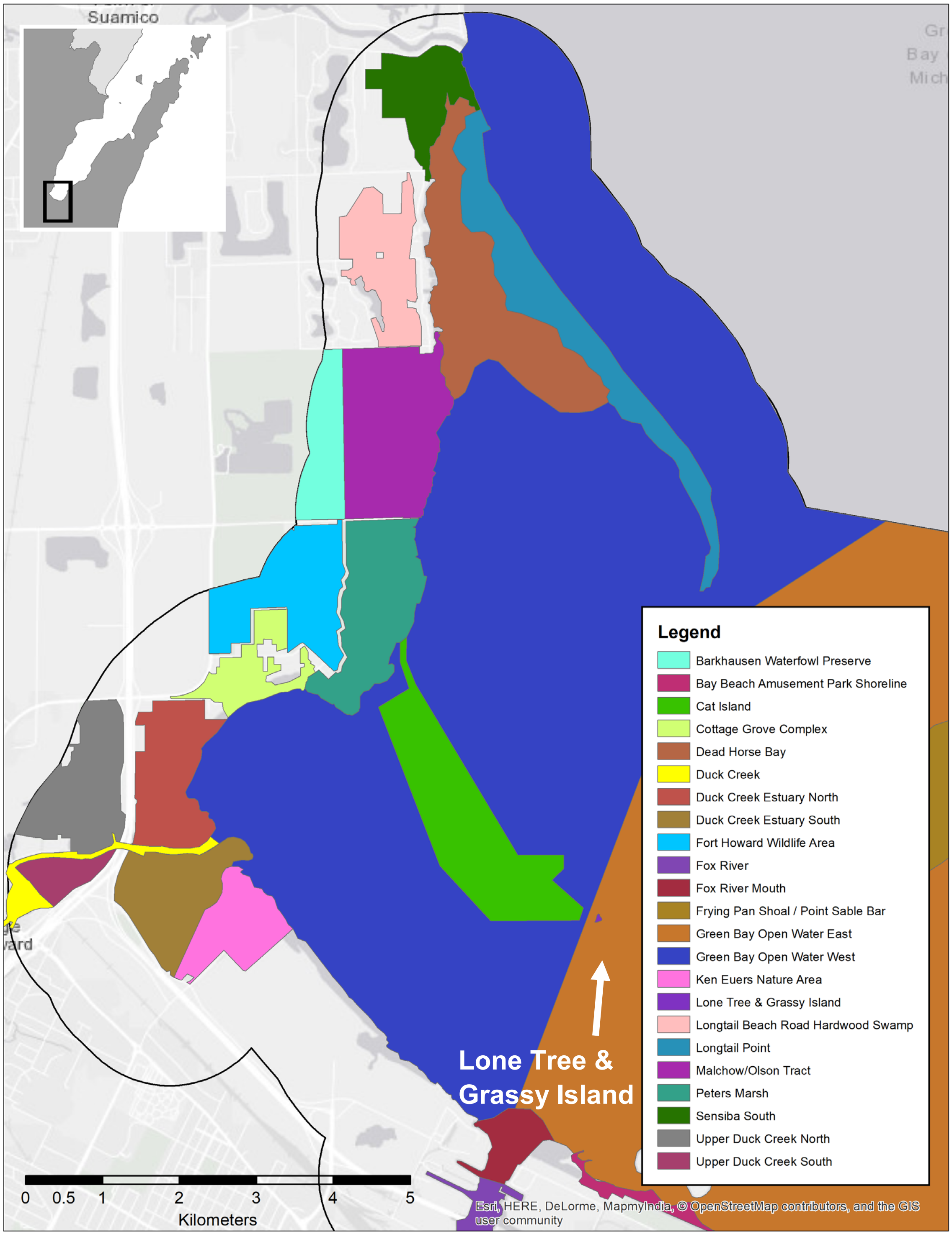


Figure 1.3. “Priority areas” along the west shore of the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC) in northeastern Wisconsin. “Priority areas” may serve as a type of “management unit” or “focus area” for future restoration planning and contain critical fish and wildlife habitat. Each “priority area” was assigned a weight (2, 3, 4, or 5), which distinguishes those “priority areas” that provide the most critical fish and wildlife habitat (higher weights; e.g., 4 or 5) in comparison to those that provide less adequate habitat (e.g., weight of 2). Criteria used to weight each “priority area” are provided in Table 1.6. Map created by Erin Giese in ArcGIS 10.5 using an ArcGIS shapefile generated by UW-Green Bay undergraduates, Jordan Marty and Cody Becker (Environmental Systems Research Institute 2016). Basemap sources: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community.

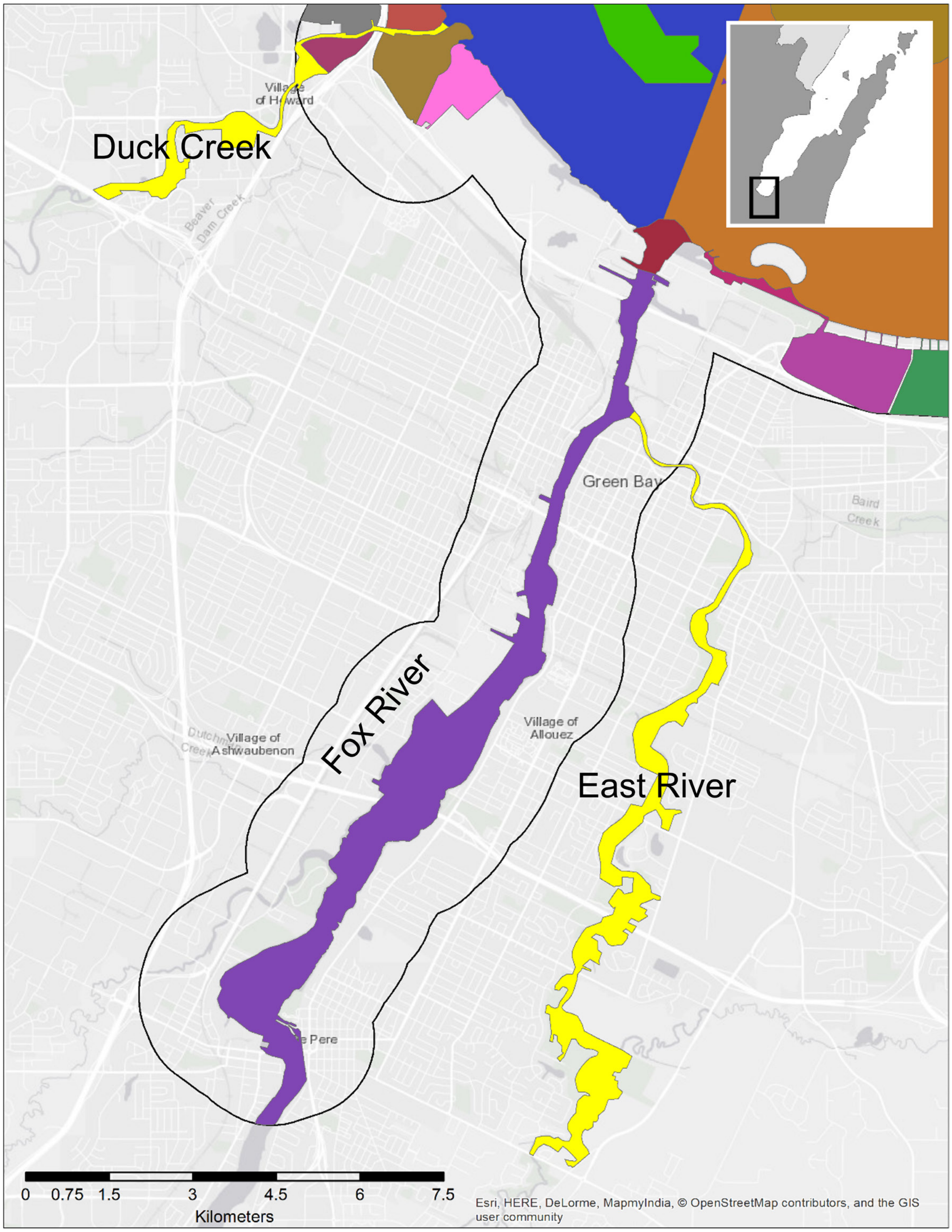


Figure 1.4. Duck Creek, Fox River, and East River “priority areas” of the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC) in northeastern Wisconsin. “Priority areas” may serve as a type of “management unit” or “focus area” for future restoration planning and contain critical fish and wildlife habitat. Each “priority area” was assigned a weight (2, 3, 4, or 5), which distinguishes those “priority areas” that provide the most critical fish and wildlife habitat (higher weights; e.g., 4 or 5) in comparison to those that provide less adequate habitat (e.g., weight of 2). Criteria used to weight each “priority area” are provided in Table 1.6. Map created by Erin Giese in ArcGIS 10.5 using an ArcGIS shapefile generated by UW-Green Bay undergraduates, Jordan Marty and Cody Becker (Environmental Systems Research Institute 2016). Basemap sources: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community.

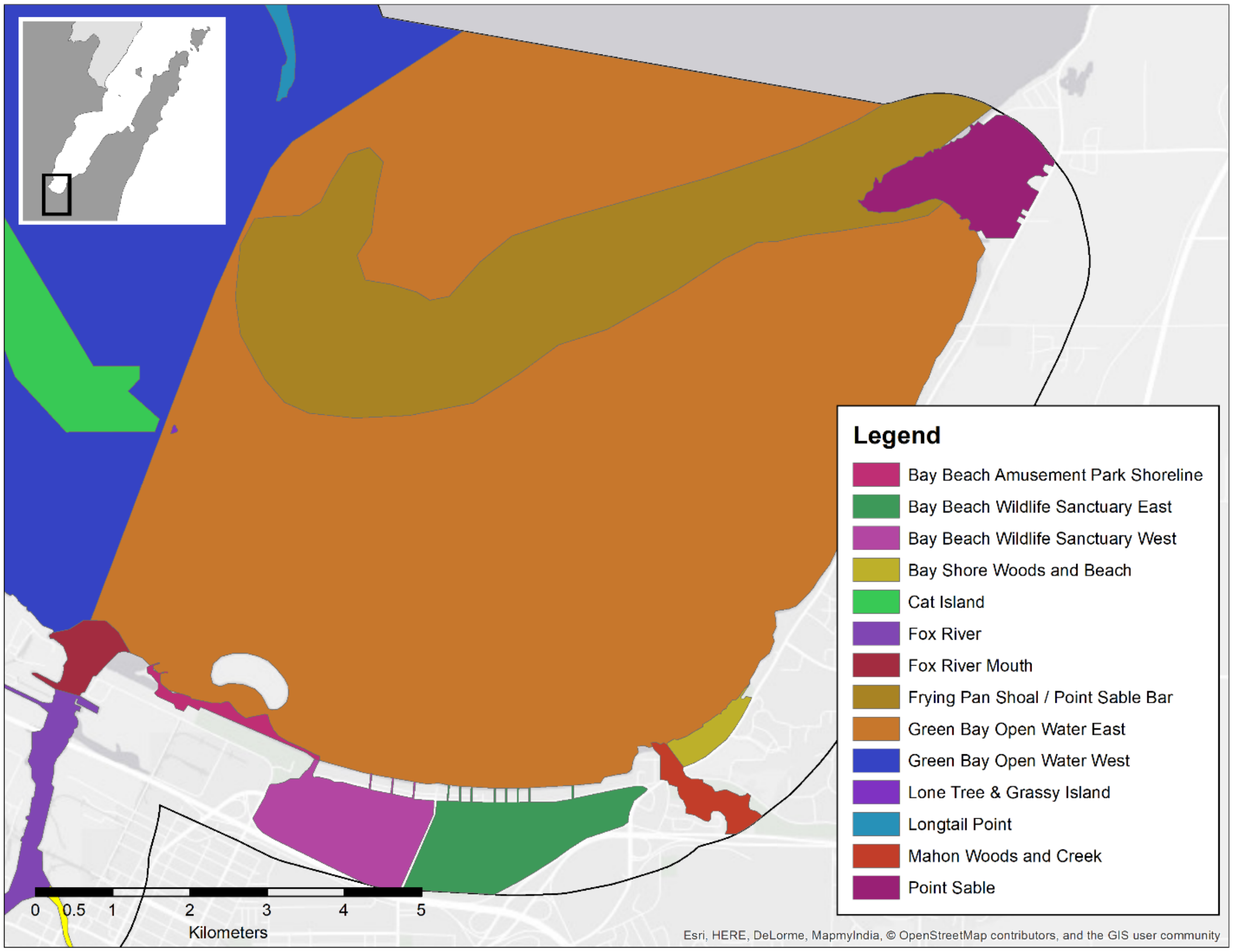


Figure 1.5. "Priority areas" along the east shore of the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC) in northeastern Wisconsin. "Priority areas" may serve as a type of "management unit" or "focus area" for future restoration planning and contain critical fish and wildlife habitat. Each "priority area" was assigned a weight (2, 3, 4, or 5), which distinguishes those "priority areas" that provide the most critical fish and wildlife habitat (higher weights; e.g., 4 or 5) in comparison to those that provide less adequate habitat (e.g., weight of 2). Criteria used to weight each "priority area" are provided in Table 1.6. Map created by Erin Giese in ArcGIS 10.5 using an ArcGIS shapefile generated by UW-Green Bay undergraduates, Jordan Marty and Cody Becker (Environmental Systems Research Institute 2016). Basemap sources: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community.

Watershed Tool

Fish and wildlife populations and habitats in the LGB&FR AOC depend not only on the officially designated aquatic ecosystem in lower Green Bay and the Fox River but also on the adjacent shoreline zone and contributing watersheds (Crosbie and Chow-Fraser 1999, Einheuser et al. 2013). The Nature Conservancy (TNC) led a parallel analysis of restoration needs and opportunities, focusing on the broader watersheds that drain into the LGB&FR AOC. Led by Nicole Van Helden and Michael Grimm, this effort was coordinated with the UW-Green Bay research team throughout the study period. TNC and UW-Green Bay staff met together regularly to coordinate information-gathering, habitat and population status assessments, and recommendations for future action.

Results from the TNC watershed analyses are provided as Part 2 of this report. TNC's contributions recognize that the surrounding watersheds are critical not only for restoring water quality in lower Green Bay and the Fox River but also for sustaining metapopulation dynamics of desirable AOC fish and wildlife species. Part 2 describes assessments of the lower Fox River watershed for critical upstream wetland projects, connectivity of watercourses for fish migration, and a specific assessment of important fish and wildlife habitats along the East River and Duck Creek riparian corridors. Results are available as an online decision support tool, fulfilling one of the most important and ambitious goals of this project.

RESULTS

Biota Database

The UW-Green Bay project identified 1,781 different species or taxa that are known or expected to occur in the LGB&FR AOC based on contributions to the LGB&FR AOC Biota Database from 75 different data sources representing individuals, organizations, universities, agencies, reports, online databases, and other publications (Table 2.1), though six of the 1,781 records are plant communities. Some species or taxa live in the LGB&FR AOC throughout the year, while others migrate through the area or stay for a season(s) for breeding or wintering. Only 125 database records were recorded prior to the year 2000; all other records have been documented within the past 17 years.

Table 2.1. List of 1,781 species/taxon that are known or expected to occur in the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC), which are stored in the LGB&FR AOC Biota Database in MS Access. The total number of species or taxon found within each taxon group (e.g., amphibians, plants) is listed in bold with the subtaxon group (e.g., anurans, trees) listed in smaller, non-bold text.

Taxon / Subtaxon	# of Species/Taxon
Amphibians	**11**
Anurans	8
Salamanders	3
Annelids	**42**
Worms	38
Other	4
Arthropods	**435**
Arachnids	110
Crustaceans	13
Insects	310
Other	2
Birds	**284**
Passerines	135
Raptors	19
Shorebirds	34
Waterfowl	33
Other Waterbirds	44
Other Landbirds	19
Diatoms	**127**
Fish	**99**

Flatworms	**1**
Fungi	**48**
Fungi	24
Lichen	24
Invertebrates (other)	**1**
Mammals	**41**
Bats	8
Carnivorans	9
Rodents	20
Other	4
Mollusks	**38**
Clams	6
Mussels	10
Snails	20
Other	2
Nematodes (roundworms)	**2**
Plants	**635**
Reptiles	**11**
Snakes	6
Turtles	5
Plant Communities	**6**

Fourteen different taxon groupings were reported: fish, amphibians, birds, mammals, reptiles, plants, fungi, many invertebrates (e.g., arthropods, mollusks), and diatoms (Table 2.1). The taxon groups with the highest number of reported species or taxa are plants (635), arthropods (435), birds (284), diatoms (127), and fish (99), though these are already highly diverse groups in terms of species richness. Nearly all expected furbearers, waterfowl, fish, migratory ducks and waterfowl, amphibians, marsh nesting birds, colonial nesting birds, and terns have been reported.

Ten species are federally listed as endangered (3), threatened (1), or special concern (6; Table 2.2). One hundred twelve species are state listed as endangered (14), threatened (17), or special concern (81; Table 1, Appendix 8). According to the Wisconsin state rankings listed by the WDNR's Natural Heritage Inventory (2014; Table 2, Appendix 8):

- Four species are state ranked as "SU," i.e., "possibly in peril in the state, but their status is uncertain";
- 49 as "S3," i.e., "rare or uncommon in Wisconsin (21 to 100 occurrences)";
- 33 as "S2," i.e., "imperiled in Wisconsin because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extirpation from the state"; and
- 21 as "S1," i.e., "critically imperiled in Wisconsin because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extirpation from the state."

Two species are globally listed as critically imperiled and 10 species listed as vulnerable (Table 3, Appendix 8). Following the International Union for Conservation of Nature and Natural Resources (IUCN) ratings (Table 4, Appendix 8):

- 12 species are listed as near threatened;
- 6 are vulnerable;
- 3 are endangered; and
- 1 is critically endangered.

Out of the 284 birds reported in the LGB&FR AOC, 102 bird species are listed under five different bird conservation plans (Table 5, Appendix 8):

- 67 species are listed as Species of Greatest Concern watch list under the Wisconsin Wildlife Action Plan;
- 51 Partners in Flight (PIF) priorities from Bird Conservation Regions 12 and 23 and Continental Watch List species;
- 8 species listed on the Upper Mississippi River and Great Lakes Waterbird Conservation Plan;
- 13 species listed as regional and continental priorities from the Upper Mississippi River and Great Lakes Joint Venture Shorebird Plan; and
- 7 species listed as regional priorities from the North American Waterfowl Management Plan.

Table 2.2. Federally listed species (10) that are known or expected to occur in the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC), which are stored in the LGB&FR AOC Biota Database in MS Access.

Scientific Name	Common Name	Taxon	Subtaxon	Federal Status
Bombus affinis	Rusty Patched Bumble Bee	Arthropods	Insects	Endangered
Charadrius melodus	Piping Plover	Birds	Shorebirds	Endangered
Oncorhynchus tshawytscha	Chinook Salmon-	Fish		Endangered
Lithobates pipiens	Northern Leopard Frog	Amphibians	Anurans	Species of Concern
Speyeria idalia	Regal Fritillary	Arthropods	Insects	Species of Concern
Chlidonias niger	Black Tern	Birds	Other Waterbirds	Species of Concern
Sterna hirundo	Common Tern	Birds	Other Waterbirds	Species of Concern
Ammodramus henslowii	Henslow's Sparrow	Birds	Passerines	Species of Concern
Vermivora chrysoptera	Golden-winged Warbler	Birds	Passerines	Species of Concern
Calidris canutus	Red Knot	Birds	Shorebirds	Threatened

Critical Biotic and Abiotic Elements of the AOC

Fish and Wildlife Populations

Thousands of animal species occur in the LGB&FR AOC, ranging from inconspicuous and poorly known microorganisms to large, spectacular vertebrates like lake sturgeon (*Acipenser fulvescens*) and American White Pelican (*Pelecanus erythrorhynchos*). Tracking or even identifying all of these species is impossible, so we have identified focal taxa (Lambeck 1997), extending the umbrella species concept (Roberge and Angelstam 2004, Branton and Richardson 2011) to include species and species groups that 1) can be cost-effectively assessed and monitored and 2) represent one or more important features of the LGB&FR AOC ecosystem. Although admittedly incomplete, our list includes high profile species that have been recognized by others as culturally significant (e.g., federal endangered or threatened species) or ecologically important (e.g., muskrat [*Ondatra zibethicus*]), plus multi-species assemblages that reflect the status of one or more important LGB&FR AOC habitats. Many of these groups have been impacted negatively by human activities, so improving their status contributes to the reversal of wildlife-related BUIs. All of the species mentioned in the LGB&FR AOC's RAP and updates (Wisconsin Department of Natural Resources 2016a) are included in the species/species groups that we have identified, although we do not discuss specific monitoring and assessment of wildlife for environmental contaminants, assuming that toxins will be covered more directly by strategies for removing other BUIs in the LGB&FR AOC.

Coastal Birds (breeding season)

Coastal birds are summer resident species that use the nearshore environment for feeding or breeding. Species in the LGB&FR AOC include Osprey (*Pandion haliaetus*), Bald Eagle (*Haliaeetus leucocephalus*), Belted Kingfisher (*Megaceryle alcyon*), Green Heron (*Butorides virescens*), Spotted Sandpiper (*Actitis macularius*), and swallows (including Purple Martin [*Progne subis*]). Colonial waterbirds, coastal wetland birds, and Piping Plover (*Charadrius melodus*) are excluded because they are part of other fish and wildlife species group categories.

This group is important because coastal birds are predators of aquatic species that depend on the coastal or nearshore environment. Swallows feed on emergent aquatic insects such as midges (Chironomidae), which may contain environmental contaminants such as polychlorinated biphenyls (PCBs), polybrominated diphenyl ether, or polycyclic aromatic hydrocarbons (Custer et al. 2017). Likewise, Osprey and Bald Eagles are apex predators that are vulnerable to bioaccumulation of toxins as well as impaired food web dynamics (Stier et al. 2016).

All of the species in this group have been confirmed as breeding in or near the LGB&FR AOC during the first three years (2015-2017) of the Wisconsin Breeding Bird Atlas 2 Project (WBBA2; eBird 2017; Figures 2.1 and 2.2). Osprey has only a single confirmed breeding record along the East River outside of the LGB&FR AOC (Wisconsin Department of Natural Resources 2016b, eBird 2017; Figure 2.1). Occupied Bald Eagle nests in WI continue to increase according to WDNR Annual Surveys (Wisconsin Department of Natural Resources 2016b, 2017; Figure 2.1). Brown County had 9 of the 1,590 occupied eagle nests in the state during 2017 (Wisconsin Department of Natural Resources 2016b, 2017). WBBA2 records show confirmed breeding records of Bald Eagle at the Cat Island Chain Restoration Site, Bay Beach Wildlife Sanctuary, Long Tail Point, Dead Horse Bay, Ken Euers Nature Area, and Barkhausen Waterfowl Preserve, though these records do not necessarily indicate nest locations but rather reports of found fledglings or adults carrying nest material (eBird 2017). Historical nests have been documented at Point Sable, although no active nests have been documented since 2014. There are a few recent breeding records of Belted Kingfisher, Green Heron, and Spotted Sandpiper (eBird 2017, Figure 2.2).

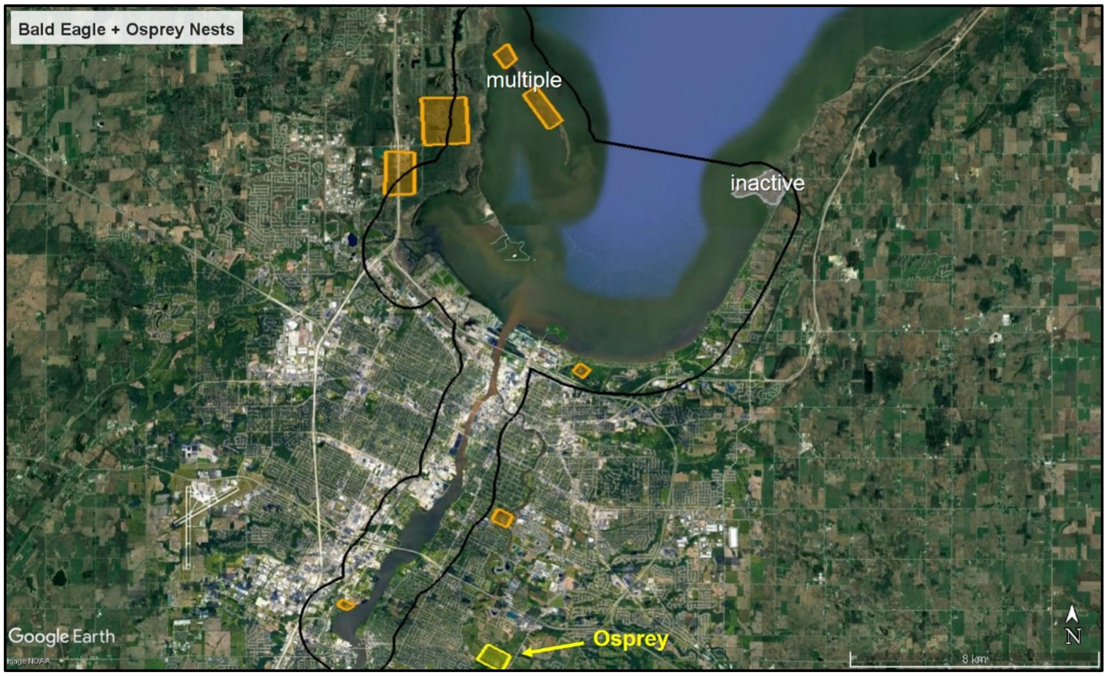


Figure 2.1. General known locations of current Bald Eagle (orange polygons) and Osprey (yellow polygon) nest locations within the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC) based on the 2016-17 WDNR Bald Eagle and Osprey Nest Surveys and reported locations from the Wisconsin Breeding Bird Atlas 2 Project (eBird 2017). Nests >0.5 km from the LGB&FR AOC study area (+ 1 km inland) were excluded, except for the one Osprey nesting location in Ledgeview. Bald Eagle nests were last reported at Point Sable in 2014 and are currently inactive. Map was made using Google Earth Pro software.

Figure 2.2. Priority areas where Belted Kingfisher (blue polygons), Green Heron (green polygons), and Spotted Sandpiper (brown polygons) are currently known to breed (plus one on private property) on the east shore within the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC) based on the Wisconsin Breeding Bird Atlas 2 Project (eBird 2017). Nests >0.5 km from the LGB&FR AOC study area (+ 1 km inland) were excluded, except for one other Belted Kingfisher nesting location in Ledgeview where an adult was found carrying food (which indicates it was carrying food to a nest or young, though neither a nest or young were found at the time). Map was made using Google Earth Pro software.

Only one recent record documenting breeding for Northern Rough-winged Swallow (*Stelgidopteryx serripennis*) has been reported in the LGB&FR AOC; Bank Swallows (*Riparia riparia*) are confirmed as breeding based on observations of recently fledged young, a breeding locality of this colonial nester has not been documented in the LGB&FR AOC (eBird 2017). There are a few breeding records of Barn Swallow (*Hirundo rustica*) in the LGB&FR AOC, particularly under bridges (e.g., Main Avenue bridge by De Pere Dam) and on the sides of buildings (eBird 2017). Cliff Swallows (*Petrochelidon pyrrhonota*) breed extensively throughout the LGB&FR AOC, including several rather large colonies under the bridges of Highway 172 over the Fox River, downtown Green Bay roads, and Interstate 41 over Duck Creek as well as on the UW-Green Bay David A. Cofrin Library (eBird 2017). Cavity-nesting Tree Swallows (*Tachycineta bicolor*) use natural cavities (e.g., hollowed out tree trunks) or artificial nest boxes and have been recently reported breeding in the LGB&FR AOC at Point Sable, UW-Green Bay campus, Bay Beach Wildlife Sanctuary West, Duck Creek, Barkhausen Waterfowl Preserve, and other locations, though nowhere along the Fox River (eBird 2017). Purple Martin, the only listed swallow species that is a state special concern species, currently breeds at a few locations on the west and east shores of the bay and at Bay Beach Wildlife Sanctuary West (eBird 2017).

The diversity and abundance of this group is high in lower Green Bay, and therefore we assign a baseline condition of 6.0. Improvements may be achieved by successful nesting of Osprey in the AOC, increase in numbers of bank-nesting Belted Kingfisher and Bank Swallow, increase nesting numbers of Bald Eagle, and overall increases in numbers of shoreline species like Green Heron, Purple Martin, and Northern Rough-winged Swallow (*Stelgidopteryx serripennis*).

A cost-effective assessment of coastal bird species will consist of point counts from coastal locations during the main avian breeding season (end of May through mid-July). A multi-species metric has not yet been developed and calibrated, but subjective improvements follow the general curve shown below (Figure 2.3). The multi-species metric will weight species in this group so that higher priority species like Bald Eagle and Osprey will contribute disproportionately to the score, which has been scaled from 0-10 in Figure 2.3.

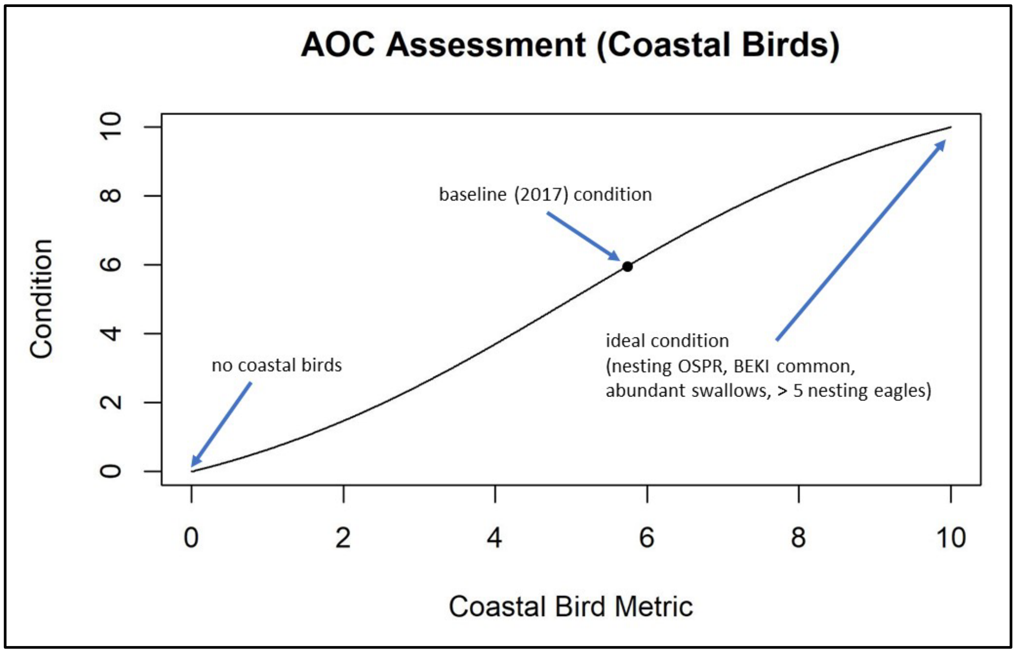


Figure 2.3. Coastal breeding bird assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the coastal bird metric (scaled from 0 [no birds] to 10 [abundant birds]), which is determined through field surveys, and the y-axis is the converted condition for a given coastal bird metric score, which ranges from poor condition (0) to good/ideal condition (10). OSPR = Osprey and BEKI = Belted Kingfisher.

Coastal birds: Osprey (left) and Tree Swallow (right). Photographs taken by Scott Giese.

Coastal Wetland Mustelids

North American river otter (*Lontra canadensis*) and American mink (*Neovison vison*) are semi-aquatic carnivores in the family Mustelidae. Otters eat fish, crayfish, frogs, muskrats, and other animals of nearshore environments, while mink, the smaller member of this pair, consume fish, muskrats, reptiles, anurans, bird eggs, and small mammals. Healthy populations of these coastal wetland mustelids reflect a productive ecosystem where bioaccumulation of toxins is at least tolerable. Although secretive, both North American river otter and American mink are excellent indicators of AOC condition and are valuable as harvested furbearers and “watchable wildlife.”

North American river otters are a flagship species of food-rich coastal areas and lower portions of rivers and estuaries, although they are scarce in polluted waters of heavily settled areas (Feldhamer et al. 2003). According to WDNR otter harvest records (Dhuey et al. 2016, Dhuey and Rossler 2017), eight otters were harvested in Brown County during 2015-2016, and nine were harvested in 2016-2017. Published densities of North American or European otters range from 0.7 to 5/km^2 or about one otter per 2-3 km of lakeshore (Erlinge 1968). More than 12 km of shoreline (excluding the Cat Island Chain Restoration Site) exists along the west shore of Green Bay; along the east shore, Point au Sable has about 2.5 km of shoreline (excluding the coastal lagoon and Wequiock Creek) and the UW-Green Bay Bay Shore Woods and Beach plus Joliet Park add another 1.5 km. Although mostly privately owned, the bay shore from Mahon Creek to the South Bay Marina is more than 4.5 km. The Fox River includes more than 5 km of developed but potentially habitable shoreline. Given suitable den sites and an uncontaminated prey base, a sustainable population of 2-3 family groups (adult female and young) certainly seem possible. We observed otters at the Bay Beach Wildlife Sanctuary and at Sensiba State Wildlife Area (just north of the LGB&FR AOC on the west shore) during this study period.

Although neither species is listed as endangered or threatened, coastal wetland mustelids are one of the highest weighted species groups because of their sensitivity to toxins, economic importance, dependence on aquatic habitats, and status as potential keystone predators (Table 1.3). Conservation measures in the LGB&FR AOC also are likely to be effective given the dependence of both mink and otters on wetlands and coastal habitats and the abundance of potential prey in the lower bay.

American mink, like North American river otter, are harvested by licensed trappers during a limited, regulated season, although unlike otters a special permit is not needed. Geographic information about mink harvest numbers are not available. However, LGB&FR AOC field workers observed mink incidentally at UW-Green Bay (multiple times), Point Sable, and the Cat Island Chain Restoration Site, suggesting that mink populations are well-established in the AOC.

Based on expert opinion and our own field observations, we assign a baseline condition of 4.0 for this group (Table 1.3). The number of coastal wetland mustelids likely can be increased most effectively by improving the availability of shelters and denning sites along the shoreline of Green Bay and contributing tributaries. Hollow trunks and logs, crevices in loose rocks, log jams, and even abandoned human structures are used by otters (Feldhamer et al. 2003). Mink numbers are strongly correlated with the amount of wetland habitat (Feldhamer at al. 2003), although availability of appropriate den sites is also important. Schladweiler and Storm (1969) reported that a single mink family in Minnesota used 20 different den sites in a 31-ha area. Bank burrows of muskrats, muskrat houses, and tree roots (especially) or hollow logs along shorelines and tributaries are commonly used by mink for shelter or maternal care (Garcia et al. 2010).

Day et al. (2016) recommend camera “traps” using quality motion-activated cameras as the most reliable method for sampling cryptic or rare species like mink and otter. Use of environmental DNA has been tested for North American river otters (Padgett-Stewart et al. 2016) and presents a possible alternative method of assessment, especially if it is combined with direct observations by camera traps. We have not yet calibrated a metric using camera traps but propose a curve (Figure 2.4) where otter observations tentatively are weighted two times that of mink. The curve is strongly nonlinear, meaning that even small increases in detections of mink and otter result in large increases in condition at low values of the abundance metric. In other words, a relatively high value of condition can be attained rather quickly if one or both species are present in the AOC.

Two final points are worth noting. The effects of trapping on abundances of coastal wetland mustelids in the LGB&FR AOC are not known, but stable numbers trapped in Brown County during recent years and the highly regulated harvest suggest that impacts of trapping at current levels are not severe. Secondly, we are aware that attempts to increase numbers of these predators is antithetical to conservation of potential prey like eggs of high priority waterbirds or turtles. We argue that the best way to protect these vulnerable bird species and turtle nest locations is to prevent access to the nests and eggs. This may involve active management, perhaps with assistance by citizen groups (in the case of turtle nest sites) and land management staff employed by local government agencies and UW-Green Bay.

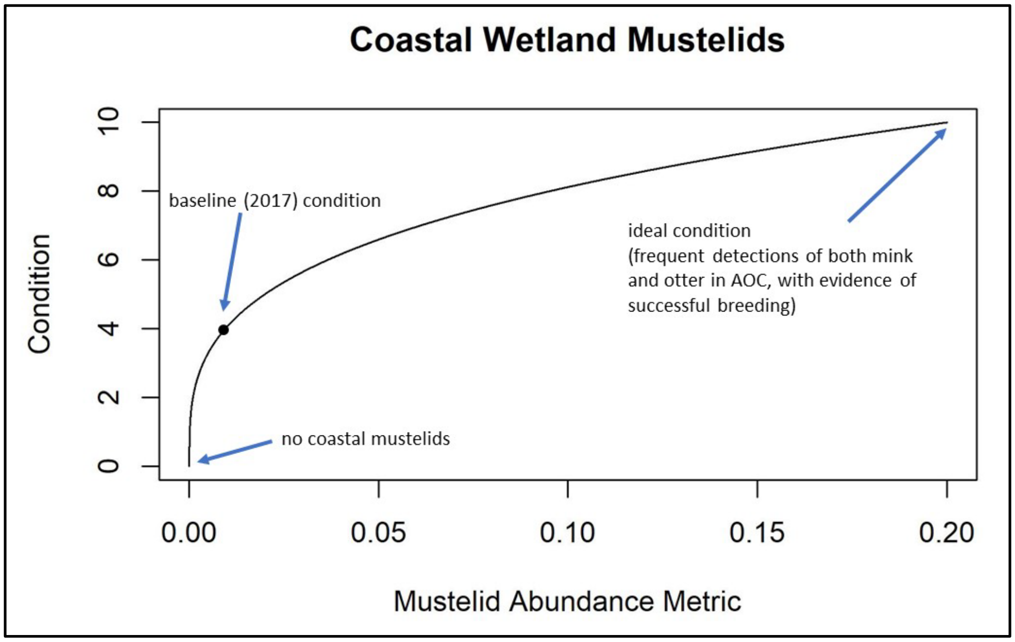


Figure 2.4. Coastal wetland mustelids' assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the mustelid abundance metric (scaled from 0 [no mustelids] to 10 [abundant mustelids]), which is determined through field surveys, and the y-axis is the converted condition for a given coastal mustelid metric score, which ranges from poor condition (0) to good/ideal condition (10).

Coastal wetland mustelids: mink (left; taken by Ryan Brady) and North American river otter (right; taken by William Schmoker from the WDNR Flickr website).

Colonial Waterbirds (breeding season)

The "colonial waterbirds" group refers to waterbirds that nest colonially, typically on islands or in rookeries, though site-specific nesting requirements vary. Species in the LGB&FR AOC include: American White Pelican (*Pelecanus erythrorhynchos*), Black-crowned Night-Heron (*Nycticorax nycticorax*), Caspian Tern (*Hydroprogne caspia*), Cattle Egret (*Bubulcus ibis*), Common Tern (*Sterna hirundo*), Double-crested Cormorant (*Phalacrocorax auritus*), Great Blue Heron (*Ardea herodias*), Great Egret (*Ardea alba*), Snowy Egret (*Egretta thula*), Herring Gull (*Larus smithsonianus*), and Ring-billed Gull (*Larus delawarensis*). This group of birds is particularly well-studied thanks to recent long-term monitoring efforts led by Thomas Erdman, Sumner Matteson, and others at the WDNR and FWS (Qualls et al. 2013).

American White Pelican, Black-crowned Night-Heron, Snowy Egret, and Cattle Egret are Wisconsin state special concern species. State endangered species include Caspian Tern and Common Tern, which is also a federal species of concern. Great Egret is state listed as threatened. Both gull species, Double-crested Cormorant, and Great Blue Heron are not state or federally listed. Herons and egrets typically nest in trees, though they have been recorded as nesting on the ground, which is rather atypical (Qualls et al. 2013). American White Pelican, Double-crested Cormorant, and the tern and gull species usually nest on the ground on sand, gravel, or cobble on islands with little to no vegetation, relatively free from human disturbance.

Because colonial waterbirds primarily eat aquatic organisms, including fish, amphibians (e.g., anurans), and aquatic macroinvertebrates, they are particularly vulnerable to bioaccumulating environmental contaminants such as pesticides, heavy metals, and PCBs, which may negatively affect reproductive success (Heinz et al. 1985, Fox et al. 1991). The importance of this population group in the LGB&FR AOC was recognized early, and the original RAP stated a specific goal of maintaining self-sustaining populations of these birds (Wisconsin Department of Natural Resources 2016a).

Historically, Black-crowned Night-Herons, Snowy Egrets, Great Egrets, Cattle Egrets, Common Terns, Double-crested Cormorants, Herring Gulls, and Ring-billed Gulls nested on the Cat Island Chain of barrier islands that extended from the west shore of the bay of Green Bay (T. Erdman, *pers. comm.*, Qualls et al. 2013). This island chain also protected a massive submergent/emergent marsh complex in the Duck Creek Delta, which likely provided food sources for these colonial birds. In the mid-1960s Cat Island proper was vegetated with willows and cottonwoods, making it suitable for tree-nesting colonial waterbirds (e.g., herons/egrets), though eventually the birds' guano killed the trees (T. Erdman, *pers. comm.*, Matteson et al. 2014). Other historic colonial nesters in lower Green Bay include Caspian Tern and Great Blue Heron; American White Pelican first nested in the lower bay in 1994 (Qualls et al. 2013, Matteson et al. 2014).

Due to extremely high water levels in the bay, massive storms, and recently hardened shorelines, most of the Cat Island Chain of islands washed away during the spring of 1973, leaving only Cat and Lone Tree Islands (Frieswyk and Zedler 2007), which persisted and are still present today. In the 1980s, a group of local conservationists proposed the bold idea of reconstructing three barrier islands, formalizing the proposal in the LGB&FR AOC's 1988 RAP. After several decades, the Cat Island Chain Restoration Site's causeway and borders of island "cells" were constructed in May 2013. This project was enabled by a partnership between the U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, Wisconsin Department of Natural Resources, and Brown County's Port of Green Bay Authority. A key element of the plan was the deposition of recently dredged material from the Green Bay shipping channel into the "cells" of the Cat Island Chain Restoration Site (Brown County Port and Resource Recovery Department). Over the next 20-30 years, the dredge material will continue to create the much-needed barrier island habitat for colonial nesting birds, fish, aquatic invertebrates, amphibians, migratory shorebirds, and other wildlife.

Today (2017), American White Pelican, Double-crested Cormorant, and Herring Gull nest on Cat Island proper (T. Prestby, *pers. comm.*, eBird 2017; Figures 2.6 and 2.9). Nesters on Lone Tree Island include American White Pelican, Double-crested Cormorant, Black-crowned Night-Heron, Great Egret, Herring Gull, and Ring-billed Gull (T. Prestby, *pers. comm.*, eBird 2017; Figures 2.6, 2.8, and 2.9). Along sections of the easternmost "cell" on the Cat Island Chain Restoration Site, American White Pelican, Caspian Tern, Black-crowned Night-Heron, and Herring and Ring-billed Gulls currently nest (T. Prestby, *pers. comm.*, eBird 2017; Figures 2.6, 2.7, 2.8, and 2.9). Just east of the mouth of the Fox River is a large Ring-billed Gull colony on the confined disposal facility (i.e., CDF), Renard Island, formerly known as Kidney Island (T. Prestby, *pers. comm.*; Figure 2.9). Both Ring-billed and Herring Gull populations have done extremely well in the past several years due to the introduction of invasive alewife (*Alosa pseudoharengus*) and rainbow smelt (*Osmerus mordax*; Qualls et al. 2013). Once Great Egrets started nesting on these barrier islands, two rarer species, Cattle and Snowy Egrets left to nest elsewhere due to the aggressive behavior of Great Egrets (Qualls et al. 2013: T. Erdman, *pers. comm.*). Common Terns have nested on artificial platforms installed and monitored by the WDNR and U.S. Fish and Wildlife Service for the past few years (Figure 2.7). Initially, a platform was installed on the southwestern side of the westernmost "cell," which was used by Common Terns in 2015, though the platform has since been removed. Instead, two nesting platforms were installed in between the westernmost and central "cells" and were used by Common Terns in 2016 and 2017.

A multispecies metric is appropriate for assessing and monitoring condition of nesting colonial waterbirds in the LGB&FR AOC. Not all species have equal priority, of course, and in some cases even desirable species may exceed healthy population levels. To account for these differences, an abundance-condition curve (Figure 2.5) can be developed for each of the 11 species in this group, similar to the species biotic response curves used in IEC calculations (see the Tributary Fish species account). Expert opinions from regional biologists as well as information from other Great Lakes sites can help formulate these curves, which will provide the basis for an IEC-like (maximum likelihood) index of condition for colonial waterbirds (Gnass Giese et al. 2015). New information can inform objective changes in these curves, which essentially identify the optimal, realistic population size or number of colonies for each species. For example, the optimal number for rare colonial-nesting species like Common Tern might be 4 distinct nesting colonies with 10 or more individuals each; even higher numbers would be desirable, but this number might represent the highest realistic target. The optimal number of American White Pelicans might be 850 nests; higher numbers than the optimal could lead to problems like impacts on recreational fisheries (Rudstam et al. 2004). The numbers given here are speculative and should not be used as recommendations; however, they illustrate the types of information that will be needed to set an objective quantitative target for colonial waterbirds.

We have assigned a baseline condition of 5.0 for this group since some colonial nesting species are doing rather well (gulls, Double-crested Cormorant, and American White Pelican), while other species are only marginally successful in the LGB&FR AOC, particularly the state endangered terns and herons/egrets. Improvements may be achieved by improving nesting structures for Common Terns and possibly other species, controlling undesirable invasive plant species, enhancing the quality and extent of emergent/submergent marsh to improve food sources, and minimizing human disturbance during the nesting season. A habitat and wildlife management plan for the Cat Island Chain Restoration Site and neighboring islands will be especially important to address invasive plant species control, strategic placement of dredge material, public access restrictions, predator control, shoreline management, and balancing the needs of listed species (e.g., state endangered terns) with those that are more common (e.g., gulls).

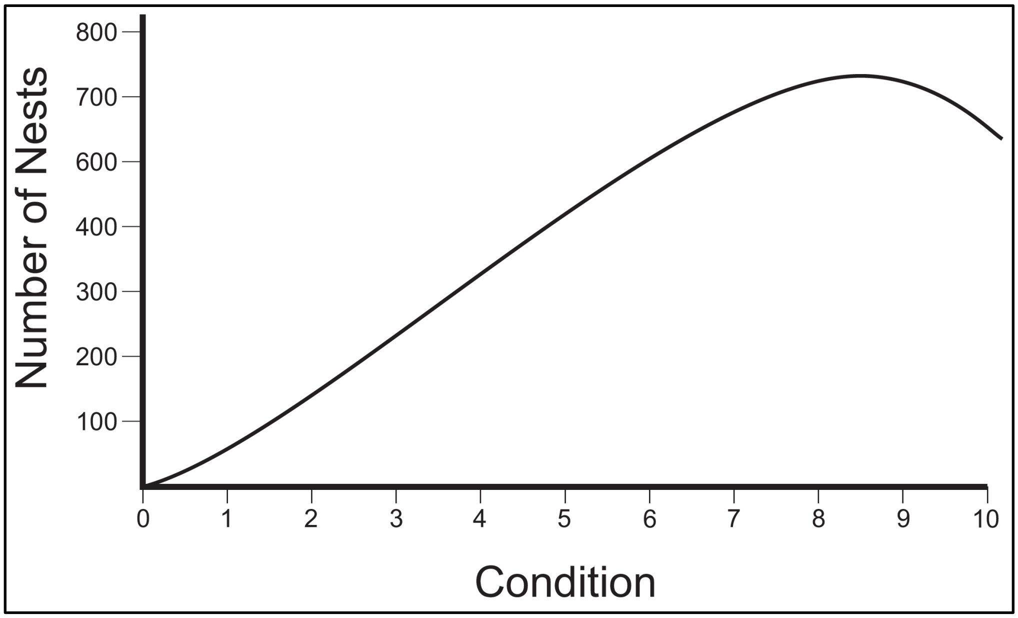


Figure 2.5. Example of a condition curve for colonial waterbirds (breeding) in the Lower Green Bay and Fox River Area of Concern, patterned after the biotic response (BR) functions of Howe et al. (2007). Curves like this for each of the 11 colonial waterbirds can be combined into a single IEC metric ranging from 0-10, where 0 represents the worst possible condition and 10 represents the ideal condition.

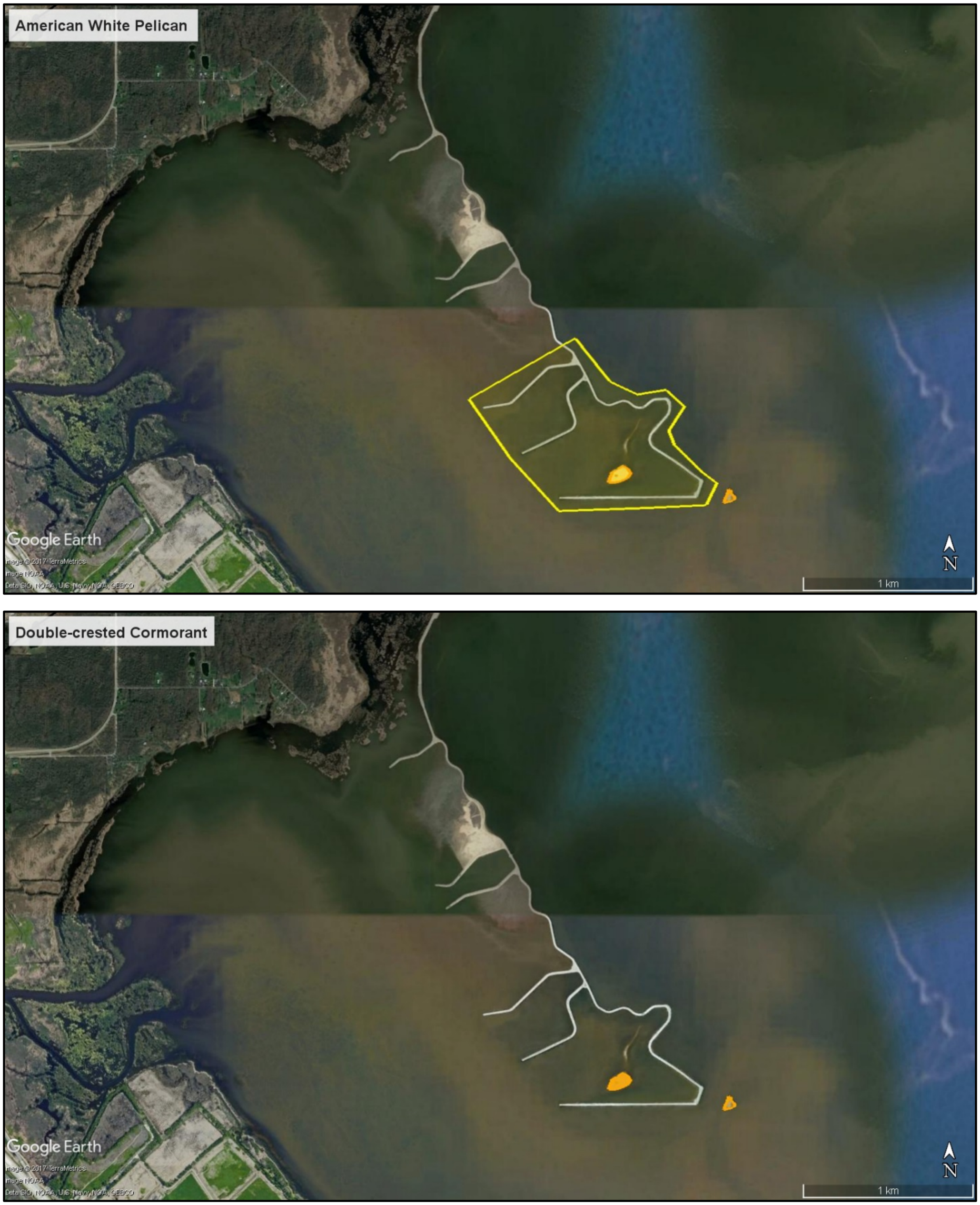


Figure 2.6. Currently known nesting locations of American White Pelican (top) and Double-crested Cormorant (bottom) within the Lower Green Bay and Fox River Area of Concern based on on-going monitoring efforts (T. Prestby, *pers. comm.*) and the Wisconsin Breeding Bird Atlas 2 Project (eBird 2017). Note that the yellow polygon on the American White Pelican map indicates that they nest along the easternmost “cell” of the Cat Island Chain Restoration Site. Map was made using Google Earth Pro software.

Figure 2.7. Currently known nesting locations of Caspian Tern (top) and Common Tern (bottom) within the Lower Green Bay and Fox River Area of Concern based on on-going monitoring efforts (T. Prestby and J. Martinez, *pers. comm.*) and the Wisconsin Breeding Bird Atlas 2 Project (eBird 2017). Two nesting platforms were artificially built for Common Terns by the WDNR. Note that the large orange polygon on the Caspian Tern map indicates that they nest along the easternmost “cell” of the Cat Island Chain Restoration Site. Map was made using Google Earth Pro software.

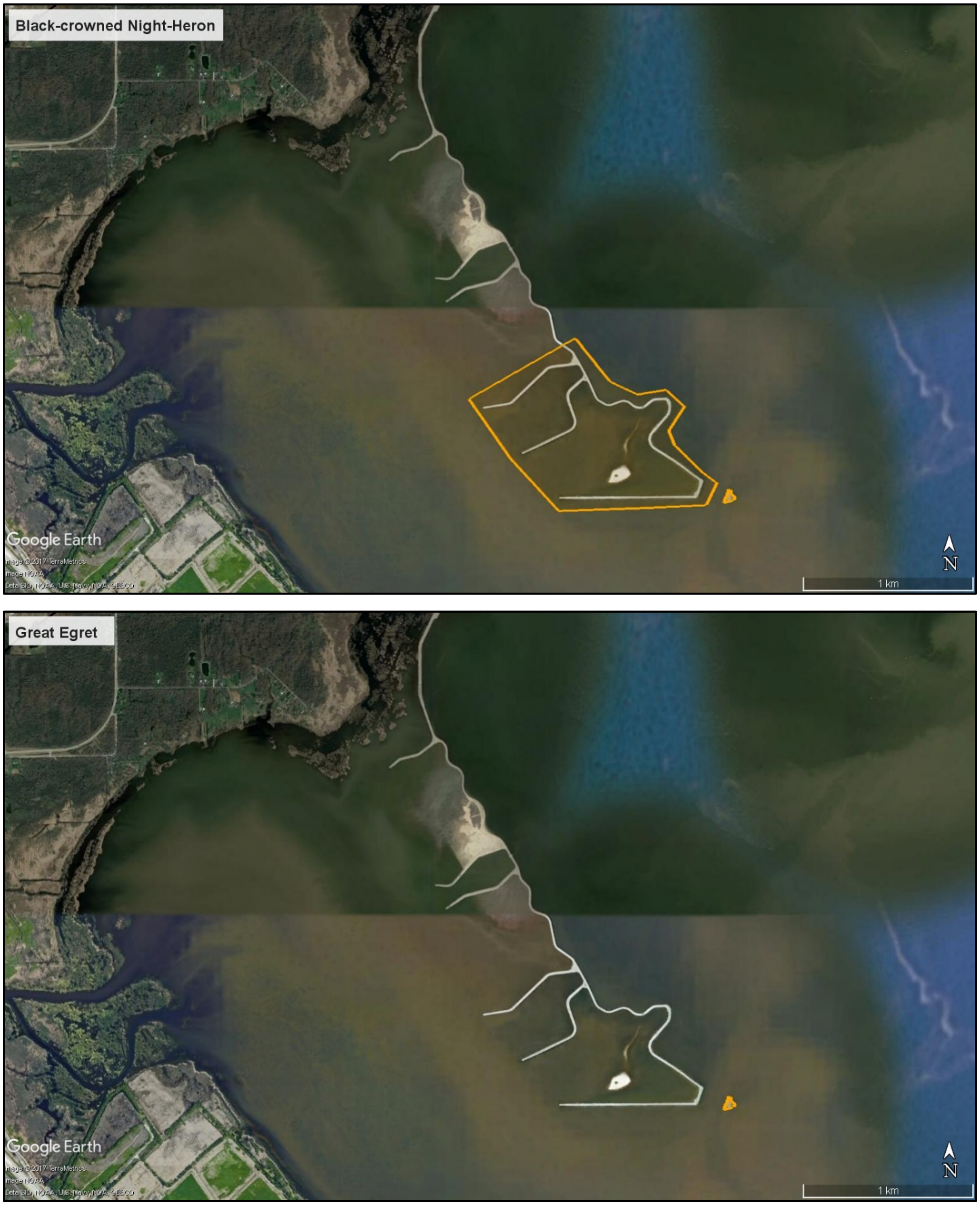


Figure 2.8. Currently known nesting locations of Black-crowned Night-Heron (top) and Great Egret (bottom) within the Lower Green Bay and Fox River Area of Concern based on on-going monitoring efforts (T. Prestby, *pers. comm.*) and the Wisconsin Breeding Bird Atlas 2 Project (eBird 2017). Note that the large orange polygon on the Black-crowned Night-Heron map indicates that they nest along the easternmost “cell” of the Cat Island Chain Restoration Site. Map was made using Google Earth Pro software.

Figure 2.9. Currently known nesting locations of Herring Gull (top) and Ring-billed Gull (bottom) within the Lower Green Bay and Fox River Area of Concern based on on-going monitoring efforts (T. Prestby and T. Erdman, *pers. comm.*) and the Wisconsin Breeding Bird Atlas 2 Project (eBird 2017). Note that the yellow polygon on the Herring Gull map indicates that they nest along the easternmost "cell" of the Cat Island Chain Restoration Site. Map was made using Google Earth Pro software.

Colonial waterbirds: American White Pelican (left; taken by Scott Giese) and Caspian Tern (right; taken by Thomas Prestby).

Fox River Fish

Despite more than a century of agricultural, municipal, and industrial pollution, the seven miles of the lower Fox River from the De Pere Dam to the waters of Green Bay today support one of the most productive recreational fisheries in Wisconsin and probably in the entire western Great Lakes region. The primary target is trophy-sized walleye (*Sander vitreus*) that migrate in early spring from lower Green Bay to the Fox River to spawn in the rocky, oxygen-enriched waters below the De Pere Dam. During the rest of the year, walleyes and other species, including yellow perch (*Perca flavescens*), white bass (*Morone chrysops*), lake whitefish (*Coregonus clupeaformis*), channel catfish (*Ictalurus punctatus*), flathead catfish (*Pylodictis olivaris*), and lake sturgeon (*Acipenser fulvescens*), are taken or caught and released during regulated seasons.

The Fox River fish group includes these game fish and other medium-sized to large native fish species that have been recorded in the lower Fox River historically (Table 2.2; Becker 1983). Lake sturgeon is a state-listed special concern species and is considered “vulnerable” in the state (S3 rank). The most critical life stage for this fish group is during spawning, for which they generally need large rivers or lakes (S. Hogler, *pers. comm.*).

Table 2.2. List of species in the Fox River fish category and their associated statuses. MPCA = Minnesota Pollution Control Agency.

Family	Species	Status
Acipenseridae	Lake sturgeon (*Acipenser fulvescens*)	Wisconsin species of special concern
Amiidae	Bowfin (*Amia calva)*	top carnivore (Lyons 1992)
Catostomidae	Quillback (*Carpoides cyprinus*)	native omnivore (Lyons et al. 2001)
Catostomidae	Bigmouth buffalo (*Ictiobus cyprinellus*)	native insectivore (Lyons et al. 2001)
Catostomidae	Shorthead redhorse (*M. macrolepidotum*)	historically present (native insectivore)
Catostomidae	Silver redhorse (*M. anisurum*)	historically present (native insectivore)
Catostomidae	White sucker (*Catostomus commersonii*)	recommended by S. Hogler (*pers. comm.*)
Centrarchidae	Rock bass (*Ambloplites rupestris*)	sensitive (MPCA 2014)
Centrarchidae	Pumpkinseed (*Lepomis gibbosus*)	intolerant in Ohio (Angermeier and Karr 1986)
Centrarchidae	Green sunfish (*Lepomis cyanellus*)	tolerant insectivore (Lyons et al. 2001)
Centrarchidae	Bluegill (*Lepomis macrochirus*)	native insectivore (Lyons et al. 2001)
Centrarchidae	White crappie (*Pomoxis annularis*)	native carnivore (Lyons et al. 2001)
Centrarchidae	Black crappie (*Pomoxis nigromaculatus*)	native carnivore (Lyons et al. 2001)
Esocidae	Northern pike (*Esox lucia*)	top carnivore

Esocidae	Muskellunge (*Esox masquinongy*)	top carnivore
Gadidae	Burbot (*Lota lota*)	native carnivore (Lyons et al. 2001)
Ictaluridae	Black bullhead (*Ameiurus melas*)	insectivorous (Lyons 1992)
Ictaluridae	Brown bullhead (*Ameiurus nebulosus*)	insectivorous (Lyons 1992)
Ictaluridae	Yellow bullhead (*Ameiurus natalis*)	insectivorous (Lyons 1992)
Ictaluridae	Channel catfish (*Ictalurus punctatus*)	native carnivore
Ictaluridae	Flathead catfish (*Pylodictis olivaris*)	native carnivore
Lepisosteidae	Shortnose gar (*Lepisosteus platostomus*)	top carnivore (Lyons 1992)
Lotidae	Burbot (*Lota lota*)	top carnivore (Lyons 1992)
Percidae	Log perch (*Percina caprodes*)	intolerant, sensitive (MPCA 2014)
Percidae	Sauger (*Sander canadensis*)	top carnivore (Lyons 1992)
Percidae	Walleye (*Sander vitreus*)	top carnivore (Lyons 1992)
Percidae	Yellow perch (*Perca flavescens*)	insectivorous, top carnivore (Lyons 1992)
Percichthyidae	White bass (*Morone chrysops*)	native carnivore (Lyons et al. 2001)
Salmonidae	Lake whitefish (*Coregonus clupeaformis*)	historically important native carnivore
Sciaenidae	Freshwater drum (*Aplodinotus grunniens*)	native insectivore (Lyons et al. 2001)

Walleye tend to be associated with large lakes and rivers, such as the Fox River, and are mainly bottom dwellers, spending time in deep waters during the day and foraging near the surface at dusk. They feed on bullhead (*Ameiurus* sp.), yellow perch (*Perca flavescens*), minnows, crayfish, aquatic worms, and other small prey items (Mecozzi's walleye fact sheet). They spawn in waters between 0.5 m and 3 m deep with reefs or shoreline rock, including downstream of the De Pere Dam in the Fox River (S. Hogler, *pers. comm.*, Figure 2.10a). Young juvenile/fingerling walleye utilize open water and shoreline areas, while adults primarily use the open waters of large rivers and lakes (S. Hogler, *pers. comm.*). During the early 1900s, walleye populations in lower Green Bay were nearly extirpated because of water pollution, over-fishing, and habitat destruction; however, WDNR biologists' fry and fingerling stocking efforts in the 1970s and 1980s in the Fox River just south of the Mason Street Bridge (Figure 2.10a) has significantly helped walleye populations recover to the point that they are now self-sustaining (Qualls et al. 2013, Hogler et al. 2015). Restored walleye spawning areas (e.g., reefs) are located at Voyageur Park, Ashwaubomay Memorial River Park, and Fox Point Boat Launch (Figure 2.10a).

Lake sturgeon are found in large rivers and glacial lakes of North America from the Mississippi River to Hudson Bay (Becker 1983). Along the bottom of rivers or lakes, they feed on small invertebrates, such as snails, leeches, and insects, using suction since they lack teeth (Lake Sturgeon Webpages). They need rocks and warm waters (11.7-15°C [53-59°F]) for spawning with adequate stream flow and regularly spawn below the De Pere Dam on the Fox River (S. Hogler, *pers. comm.*, Lake Sturgeon Webpages; Figure 2.10a). Juveniles tend to use rivers, mouths of rivers, and muddy and silty areas, while adults use large rivers, open water, and shorelines (S. Hogler, *pers. comm.*). During the early 1900s, lake sturgeon populations in Lake Michigan rivers significantly declined due to overharvesting, poor water quality, and fish passage barriers, though currently their populations are relatively self-sustaining through conservation efforts (Donofrio et al. 2015).

Lake whitefish adults and juveniles are bottom dwellers in open-water habitats, where they stay as deep as ~100 m during the daytime and then move to shallower waters at night where they eat invertebrates and small fish (S. Hogler, *pers. comm.*, Lake Whitefish, University of Wisconsin Sea Grant Species Account). They prefer to spawn along shorelines with rock, including downstream of the De Pere Dam in the Fox River (S. Hogler, *pers. comm.*; Figure

2.10a). Historically, huge numbers of lake whitefish once inhabited the Great Lakes; however, their populations were decimated during the twentieth century due to overharvesting and the destruction of important spawning areas by the lumber industry (Lake Whitefish University of Wisconsin Sea Grant Species Account, Qualls et al. 2013). Their preferred prey, *Diporeia* (zooplankton), largely vanished with the arrival of zebra/quagga mussels (*Dreissena* spp.; Lake Whitefish University of Wisconsin Sea Grant Species Account). Once water quality improved, lake whitefish returned to the Fox River and other rivers roughly 10-15 years ago, after being absent for over 100 years (Qualls et al. 2013, S. Hansen as reported in Parr 2016).

Adult channel and flathead catfish use open water and rivers, including the Fox River, where they favor deep holes and woody debris. Juveniles tend to use a broader variety of microhabitats in rivers (S. Hogler, *pers. comm.*). Like the other Fox River Fish species, catfish are bottom dwellers and are most active at night in shallow waters (Catfish Fact Sheet). Adult channel catfish diet is broad since they are mostly opportunistic scavengers and may consume small fish, crayfish, carrion, and snails, while flathead catfish eat live fish (Catfish Fact Sheet, Wisconsin Department of Natural Resources 2016c). Catfish typically build nests along undeveloped shorelines (S. Hogler, *pers. comm.*). Both species spawn in the Fox River, though not at the De Pere Dam. Channel catfish also spawn in other tributaries or in the bay itself (S. Hogler, *pers. comm.*). These two species of catfish are relatively tolerant to turbid waters, though individuals prefer clearer, slower waterways (Catfish Fact Sheet). Historically, catfish were regularly caught by early fishermen in the late 1880s (Qualls et al. 2013).

Fox River fish are good indicators of ecological condition in the LGB&FR AOC because they consume prey that depend on the coastal or nearshore environment, which may contain environmental contaminants such as polychlorinated biphenyls (PCBs) and mercury (Catfish Fact Sheet, Qualls et al. 2013). Predators higher in the food chain that consume Fox River fish species (including people) are vulnerable to bioaccumulation of these organic toxins, which can cause reproductive issues or deformities (Qualls et al. 2013). Today, fish advisories recommending safe fish consumption by species are regularly posted at boat launches and parks along the Fox River.

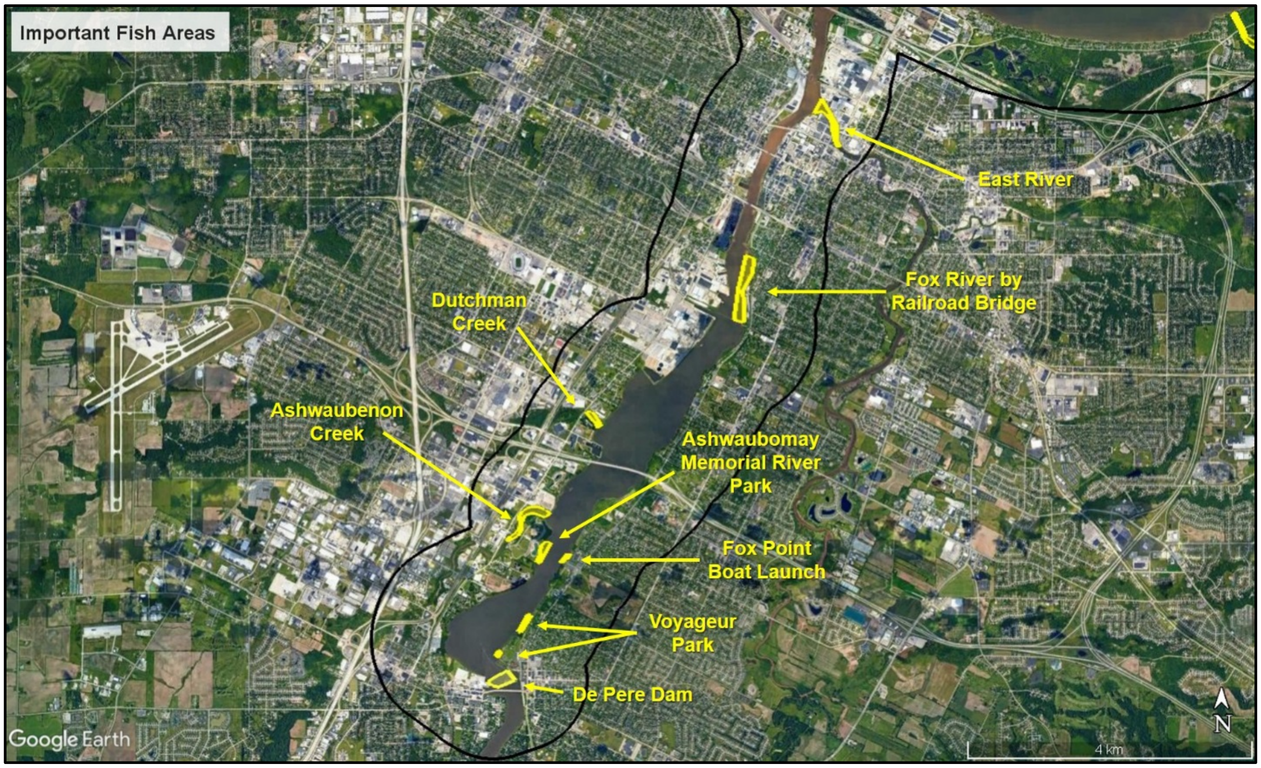


Figure 2.10a. Important fish areas of the Fox River within the Lower Green Bay and Fox River Area of Concern based on Wisconsin Department of Natural Resources records (S. Hogler and C. Larscheid, *pers. comm.*). Map was made using Google Earth Pro software.

Many fish species, including those in the Fox River fish group, were originally listed in the RAP because of poor quality spawning habitat, impaired reproduction, low overall fish diversity, poor water quality, fish passage barriers, and introduction of invasive species such as zebra/quagga mussel and sea lamprey; Qualls et al. 2013, Wisconsin Department of Natural Resources 2016a).

We assign a baseline condition of 5.0 for this group based on expert opinion and recent field assessments. Generally, some of the important fish populations in the Fox River (e.g., walleye, lake whitefish) are recovering, presumably due to improved water quality and spawning habitats and in some cases stocking. Qualls et al. (2013) reported that the overall condition of walleye is “good” (i.e., “presently meeting ecosystem objectives or otherwise is in acceptable condition”) with an unchanging trend. Lake sturgeon in the AOC are considered a “recovering population” whose status is improving. The overall conditions of lake whitefish and both catfish species are less certain, though experts suspect they are doing relatively well (i.e., condition score of 5.0; S. Hogler, *pers. comm.*). Among all species in the Fox River fish group, walleye populations appear to be doing the best.

Improvements in the condition of Fox River fish may be achieved by identifying and removing barriers to potential spawning areas, improving substrate (including gravel, riffles, and pool habitat), reducing sediment pollution, and creating or restoring important fish spawning and nursery habitats, such as rocky reefs, gravel, cobble, and woody debris. The De Pere Dam is a particularly critical area for spawning of walleye, lake sturgeon, and undoubtedly other species of Fox River fish. The combination of rocky substrate and perhaps oxygenated water from the turbulence associated with the dam provide favorable conditions for spawning and early development of juvenile fish. Backwater habitats in the vicinity of the De Pere Dam and possibly Ashwaubomay Park, National Railroad Museum, and St. Francis Park provide potentially significant restoration or habitat improvement opportunities. Specific spawning locations of catfish are mostly unknown, so identifying and mapping spawning areas that could be restored or enhanced would be helpful.

Lyons et al. (2001) describe a fish-based Index of Biotic Integrity (IBI) for warmwater rivers in Wisconsin, including the lower Fox River. This provides a ready-made metric for assessing condition of the Fox River fish community in the context of comparable rivers in Wisconsin. The proposed field method of electroshocking along 1 mile (1,600 m) of contiguous, relatively shallow shoreline areas along the main river channel is cost effective, requiring only 2-4 hr for a crew of 2-3 trained fish biologists. However, we argue that an even simpler metric using the same sampling protocol would avoid some of the shortcomings of the Lyons et al. IBI, including its reliance on artificial or ambiguous fish categories (e.g., riverine species, intolerant species), use of locally or seasonally unpredictable variables like biomass or species richness, and subjective smoothing of scoring criteria into categories like “poor”, “fair”, and “good.” Use of a probability-based indicator, called the Index of Ecological Condition (Howe et al. 2007), enables the use of presence/absence field data and takes into account the specific responses of species, which might fit different fish categories depending on life history stage or variable diet (Figure 2.10b). Sensitivities of different species in large rivers would need to be documented before such a metric could be used, but the already-completed work of Lyons et al. (2001) could be applied for this purpose.

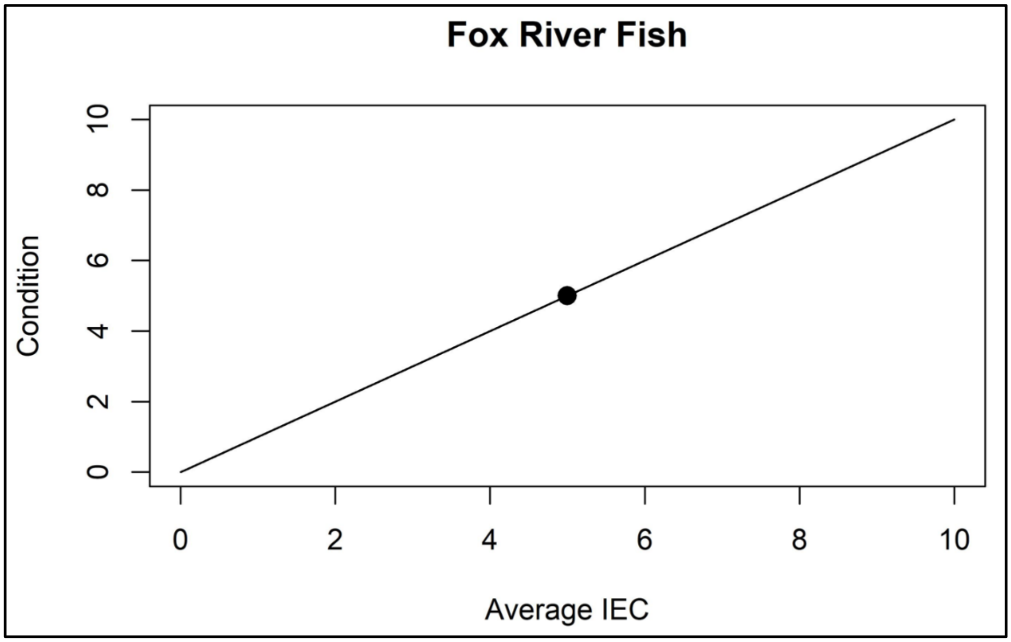


Figure 2.10b. Fox River fish assessment for the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC). The x-axis represents the Fox River fish metric (scaled from 0 [worst condition] to 10 [ideal condition]), which is determined through field surveys and application of the Index of Ecological Condition (IEC; Howe et al. 2007).

Fox River fish: lake sturgeon (left; taken by Rob Elliot) and walleye (right; illustration by Virgil Beck from WDNR Flickr website).

Freshwater Unionid Mussels

North America supports the most diverse freshwater mussel fauna on Earth. The Mississippi River basin, in particular, contains more than three times the number of native mussel species as in the Amazon-Orinoco Basin in South America, more than three times the number of species in the entire Palearctic region (Europe and northern Asia), and more species than in any of the world's drainage basins except the Gulf Coast region of the U.S. (Haag 2012). Freshwater mussels of the Laurentian Great Lakes are derived mainly from post-glacial colonization of species from the Mississippi drainage. Lake Michigan mussels (31 species, all in the family Unionidae) are believed to have originated from range expansions through a former connection to the Wisconsin River, which drains directly into the Mississippi River in southwestern Wisconsin (van der Schale 1963).

Unfortunately, over 70% of the word's freshwater mussel species are either extinct or imperiled (Strayer 1983, Ricciardi and Rasmussen 1999, Watters and Flaute 2010). Not only are these filter-feeders sensitive to sediment pollution, but individuals are long-lived (i.e., populations are slow to recover from disturbances) and have complex life cycles with a larval host, usually a fish (Table 2.3) or aquatic amphibian like the common mudpuppy (*Necturus maculosus*).

The LGB&FR AOC appears to have lost most, if not all, of its native mussel fauna. Dead shells are easily found along the Green Bay shoreline today, bearing testimony to a recent unionid community that has given way to invasive dreissenid mussels (*Dreissena polymorpha* and *D. bugensis*) in this highly modified, hypereutrophic aquatic ecosystem.

We weighted unionid mussels in the top quartile of species/species groups (Table 1.3) based on their sensitivity to pollution, dependence on the aquatic environment, and conservation status. This ranking could potentially be even higher, as several authors have argued that unionid mussels are keystone species in freshwater ecosystems (Gutiérrez et al. 2003, Zimmerman and de Szalay 2007, Vaughn et al. 2008). Because of their near extirpation and superabundance of competing dreissenid mussels, however, we suggest that the status of native freshwater mussels as keystone species would take many years to re-establish.

Unionid mussels are not mentioned in the original RAP targets for the degradation of fish and wildlife BUI (Wisconsin Department of Natural Resources 2016a), but native mussels are increasingly recognized as an important, though underappreciated and critically imperiled element of freshwater ecosystems in the Great Lakes (Metcalfe-Smith et al. 1998, Schloesser et al. 2006, Weinzinger 2017, Weinzinger et al. *in prep*., and others).

Weinzinger (2017) describes a rapid assessment method that we recommend for our unionid mussel condition metric. Although designed for wadable streams, the protocol consists of a series of six 10 m x 1 m sample units, evenly spaced along a 100 m transect. Equivalent 100 m segments at appropriate depths in the open bay can be compared with other bay samples as well as samples in tributaries and rivers. Weinzinger's method has been applied by citizen scientists and teams from UW-Green Bay undergraduate ecology courses. Simple presence/absence of species within each sample unit provides a robust variable that can be used to assess progress toward a desired future condition. We suggest that five viable mussel beds with at least three species overall might be attainable in the LGB&FR AOC, setting our ideal condition (10) for the mussel assessment metric (Figure 2.11). A simple variable (M) to assess progress toward this target is M = mb x sp, where mb = the number of mussel beds or local populations in the AOC and sp = the total number of unionid mussel species present as breeders (Figure 2.11).

We assigned a condition of 1.0 for freshwater unionid mussels in the LGB&FR AOC today based on the presence of nearby source populations but recent records of just a single species, giant floater (*Pyganodon grandis*), at a few localities (J. Weinzinger, *pers. comm.*). The combination of high priority weight and low current condition ensures that any progress toward reestablishing native mussels in the LGB&FR AOC will have a strong impact on progress toward the overall removal of the degradation of fish and wildlife populations BUI.

Weinzinger (2017) found no live mussels at a site in Duck Creek, approximately 5 km inland from the Green Bay shore. Farther upstream, however, his sampling team found more than 500 individuals of 12 species (*Actinonaias ligamentina*, *Alasmidonta viridis*, *Amblema plicata*, *Anodontoides ferussacianus*, *Eliptio dilatata*, *Fusconaia flava*, *Lampsilis siliquoidea*, *Lasmigona compressa*, *Lasmigona complanata*, *Pyganodon grandis*, *Quadrula quadrula*, and *Strophitus undulatus*). Weinzinger (2017) also found seven species (including *Leptodea fragilis*, not found in Duck Creek) in the Suamico River, which empties into Green Bay just north of the AOC boundary at Longtail Point. Some of these species are restricted to streams and rivers, but others may occur along lakeshores or coastal wetlands. Nearby populations in Duck Creek and other tributaries are important because they may provide a source of individuals for re-introduction or re-colonization into the Green Bay ecosystem. Weinzinger found recent dead shells of *L. fragilis* (fragile papershell), *A. plicata* (threeridge), *L. siliquoidea* (fatmucket), and *F. flava* (wabash pigtoe) along the Point au Sable shoreline, suggesting that suitable habitat exists or at least existed recently for several species.

Projects to improve the condition of unionid mussel populations in the LGB&FR AOC may eventually involve translocation of individuals from nearby mussel beds or captive-reared populations. Before this occurs, however, additional field inventories should be conducted to search for remnant mussels. Zanatta et al. (2002) and McGoldrick et al. (2009) found thousands of unionid mussels representing 22 species in sandy nearshore areas and marshy bays in the Lake St. Clair delta, which is believed to be the largest living unionid community in the lower Great Lakes. Similar discoveries in lower Green Bay are highly unlikely, but additional inventory work clearly is needed in the LGB&FR AOC. Habitat characteristics of coastal wetlands with remnant populations of unionids include a hydrological connection with the lake, soft sediments for burrowing, and pools that are deep enough to sustain small mussel populations during periods of low water levels (Bowers and DeSzalay 2004).

Even less information is available about mussel populations or historical beds in the Fox River. Haag (2012) recommends that tailwater locations downstream of large dams have the greatest potential for restoration of mussel habitat in North America. Bednarek and Hart (2005) and others demonstrated that restoration of natural hydrologic flows downstream of dams led to significant improvement in habitat for fish, aquatic insects, and freshwater mussels. The aftermath of PCB dredging may present an opportunity for habitat improvement and, if necessary, re-establishment of mussel populations in the vicinity of the dam. Targeted control of dreissenid populations in areas with high potential for mussel success (Point au Sable, downstream Fox River from the De Pere Dam, and relatively clear water areas like Dead Horse Bay and Peter's Marsh) should be combined with translocations or protection of remnant mussel populations in the LGB&FR AOC.

Table 2.3. Freshwater mussel species observed in Duck Creek during the 2014-2015 field season by Jesse Weinzinger (2017). Host and habitat information from the Freshwater Mussels of the Upper Mississippi River, 3rd addition, 2012. *WI State Threatened species.

Scientific Name	Common Name	Host	Habitat
Actinonaias ligamentina	Mucket	Generalist, sunfishes and basses important	Medium-sized streams to large rivers with good current
Alasmidonata. viridis*	Slippershell	Probably darters or sculpins	Small to medium-sized streams
Amblema plicata	Three-ridge	Generalist, catfishes important	Medium-sized streams to large rivers, including impoundments
Anodontoides. ferussaciaanus	Cylindrical papershell	Generalist	Only inhabits small streams
Elliptio. dilatata	Spike	Darters and perches; basses and sunfishes also might be important hosts	Sloughs and main channel borders
Fusconaia flava	Wabash pigtoe	Minnows	Medium-sized streams to large rivers
Lampsilis siliquoidea	Fatmucket	Generalist, sunfishes and basses important	Shallow water near aquatic vegetation
Lasmigona complanata	White heelsplitter	Generalist	Areas with reduced flow
Lasmigona. compressa	Creek heelsplitter	Generalist	Small streams
Pyganodon grandis	Giant floater	Generalist	Areas with reduced flow
Quadrula	Mapleleaf	Catfishes	Medium-sized streams to large rivers; adjusts well to impoundments
Strophitus undulatus	Creeper	Generalist; glochidia known to complete transformation without a host	Small streams, but also in upper Mississippi River

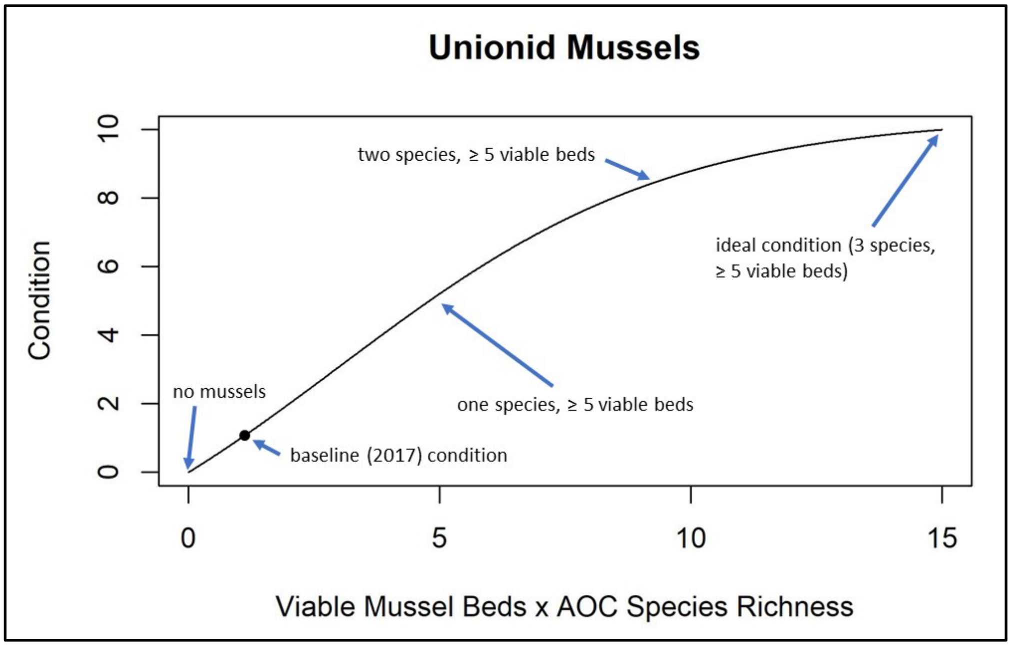


Figure 2.11. Unionid mussels' assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the unionid mussel metric (scaled from 0 [no mussels] to 10 [ideal condition]), which is determined through field surveys, and the y-axis is the converted condition for a given unionid mussel metric score, which ranges from poor condition (0) to good/ideal condition (10).

Freshwater unionid mussels: fatmucket (left) and threeridge (right). Photographs provided by the WDNR on Flickr website.

Muskrat

Muskrats (*Ondatra zibethicus*) are relatively common and are often considered pests because of their damage to shoreline or riparian structures. However, muskrats are a key element of emergent wetland ecosystems in North America and several researchers describe them as important "ecological engineers." Clark and Kroeker (1993) and Davis and van der Valk (1978) noted that muskrats are the most significant vertebrate consumer of vegetation in many North American wetlands, where their activities influence vegetation decomposition (Connors et al. 2000), the proportion of open water within the wetland (Weller 1981), and availability of nest sites for birds and other animals (e.g., Hickey and Malecki 1997). Construction of muskrat houses and runways also provide important microhabitats for invertebrates (Nelson and Kadlec 1984) and colonization habitat for wetland plants (Weller and Spatcher 1965), thus increasing wetland plant species richness.

Muskrats are herbivores that help maintain open water pockets in emergent wetlands. Image from Creative Commons.

Recent surveys (Roberts and Crimmins 2010, Ahlers and Heske 2017) have shown that muskrat populations are declining across the U.S., especially in the south. Possible causes include overall wetland loss and isolation, degradation of remaining wetland habitats, changes in hydrodynamics due to climate change or water level controls, or species interactions such as disease or competition from invasive species. Benoit and Askins (1999) found that muskrats declined in wetlands dominated by *Phragmites australis*, so muskrat numbers on a landscape scale might be an indicator of the impacts of *Phragmites* on natural wetland dynamics.

Because of their potentially critical ecological role in wetland dynamics, we treated muskrats as a single-species category in our list of important population groups. Their economic importance as furbearers and their ecological linkage to the Green Bay/Fox River aquatic ecosystem led us to assign an overall priority weighting of 13, placing them in the upper middle quartile of priority species/species groups (Table 1.3). The earlier RAP delisting targets (Wisconsin Department of Natural Resources 2016a) also identified a target of “healthy, self-sustaining, naturally reproducing populations” of muskrats and other native furbearers.

Muskrat numbers in the LGB&FR AOC can be expected to fluctuate naturally (perhaps dramatically) due to demographic factors (e.g., Errington 1951, Haydon et al. 2001) and variations in water levels in the Green Bay coastal zone. During recent relatively high water-years (2016-2017), muskrat populations appear to be thriving in Green Bay wetlands. Wolf (*pers. comm.*), for example, used June 2017 aerial imagery to estimate densities of muskrat structures of 0.5/ha at Peter’s Marsh, 2.0/ha at the Duck Creek Estuary and Dead Horse Bay, 2.85/ha at Duck Creek west, and 4/ha in the lagoon at Point au Sable. These numbers are high compared with similar studies elsewhere (Proulx and Gilbert 1984, Toner et al. 2010), although Bellrose and Brown (1941) reported a remarkable density of 8.65/ha (3.5/acre) in emergent vegetation zones of lakes with stable water levels.

Muskrat houses during winter 2014 within the lagoon of Point au Sable. Photograph courtesy of Robert Howe.

We have no information on the long-term sustainability of muskrat numbers in the LGB&FR AOC. During 2017, at least 6 local centers of abundance (separated by at least 1 km) appear to be present. While more local centers of abundance may be present in the lower bay and Fox River, especially with continued control of *Phragmites*, we have no evidence to suggest that a higher number is an ideal future condition. Instead, we emphasize the critical importance of sustainable local muskrat centers of abundance (separated by at least 1 km), which help insure persistence through both high and low water cycles. The standardized muskrat visual index (MVI) of Engeman and Whisson (2003) can be used to document muskrat numbers in parallel with muskrat structure surveys from air photos. On-the-ground surveys (using the MVI) will be especially important during low water years when muskrat structures are less apparent from air photos.

Evidence for long-term persistence of muskrats in our 6 local centers of abundance is lacking, so we conservatively assign a baseline condition score of 6.0 for the LGB&FR AOC (Figure 2.12), speculating that only half of the observed populations are persistent for 5 or more years. The desired future condition (10) will be reached when these centers of abundance can be shown to persist through both low and high-water periods. We propose a sampling scheme that places multiple standard stratified/random MVI transects within each center of abundance, recognizing that the exact location of these centers might shift as water levels rise and recede. A subjective decision (e.g., when muskrats are observed at a locality for 5 consecutive years) may be needed to establish that a local center of abundance is persistent. Persistent local populations of muskrat would help fulfill the original RAP target that “populations of traditionally harvested wildlife species are capable of supporting some level of exploitation.”

Other studies (e.g., Cotner and Schooley 2011) have shown that muskrats are tolerant of urbanization and some degree of invasive vegetation, so factors like wetland habitat loss, reduced wetland connectivity, and disruption of natural water-level fluctuations (Greenhorn et al. 2017) are most likely to threaten viability of muskrat populations (Ahlers and Heske 2017). Biotic factors like predation or disease also might be important, but these effects occur in natural populations and are most likely to be episodic even in undisturbed conditions. The most important management action to protect muskrats in the LGB&FR AOC simply might be to protect large, contiguous areas of emergent wetland vegetation, coupled with ongoing control of invasive wetland plant species like *Phragmites*.

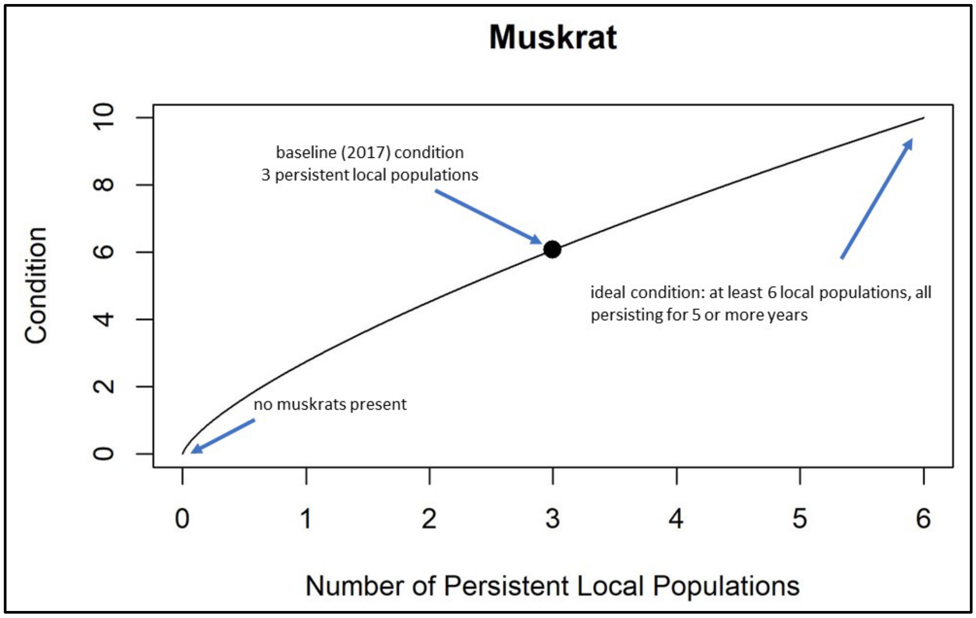


Figure 2.12. Muskrat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the number of persistent local muskrat populations (scaled from 0 [no muskrats present] to 10 [ideal condition of at least 6 local populations, persisting for 5+ years]), which is determined through field surveys. The y-axis is the converted condition, which ranges from poor (0) to good/ideal (10).

Piping Plover

The federally endangered Piping Plover (*Charadius melodus*) has rapidly become a flagship species for the LGB&FR AOC following the establishment of a breeding pair in 2016 and multiple pairs during 2017 at the Cat Island Chain Restoration Site. The Great Lakes population is by far the smallest (75-80 pairs) among North America's three regional populations of Piping Plovers (Kahler and Cavalieri 2014). (The other two populations, listed as threatened, occur on the Atlantic Coast and in the Northern Great Plains, respectively.) Piping Plover populations in the Great Lakes ranged between 492 and 682 breeding pairs in the early twentieth century, but numbers reached a low of only 17 pairs in the mid-1980s (Russell 1983). Factors likely responsible for the dramatic decline included habitat loss and degradation, disturbance from human activities, vegetation encroachment at open beach nesting areas, and disturbances at wintering habitats along the south Atlantic and Caribbean coasts and islands (Haffner et al. 2009).

Piping Plovers arrived at the Cat Island Chain Restoration Site shortly after the first sandy dredge spoils were deposited in the westernmost "cell." Shorebird researcher Tom Prestby documented a pair of territorial Piping Plovers plus several other migrant individuals in 2013. Migrants were again observed during both spring and fall of 2014. In spring 2015, three male Piping Plovers established and defended territories from mid-May until late June, although they were unable to attract a nesting female (Prestby 2015). Finally, in 2016, Piping Plovers nested successfully at the Cat Island Chain Restoration Site, producing three fledged young. This event represented the first documented nesting of Piping Plovers in lower Green Bay in more than 75 years (United States Fish and Wildlife Service 2016). During 2017, four pairs nested at the site, which had been enhanced by the addition of gravel substrate in a 6+ ha area of mostly sand dredge material**.**

Piping Plover fledged chick banded at the Cat Island Chain Restoration Site during the summer of 2017. Photograph courtesy of Robert Howe.

The area occupied by Piping Plovers at the Cat Island Chain Restoration Site is approximately 6 ha. Cairns (1982) reported that the average territory size of Piping Plovers in southern Nova Scotia was about 4,000 m^2 (0.4 ha), with distances between nests averaging only 52 m. Like the Piping Plovers at the Cat Island Chain Restoration Site during 2017, home ranges of the Nova Scotia birds obviously overlapped extensively. Haig and Oring (1988) studied 72 Piping Plover nests in Manitoba, where distance between nests ranged from 25-100 m. In the Great Lakes, Haffner et al. (2009) reported average home ranges of 2.9 ± 0.5 (SE) ha for successfully breeding Piping Plovers. Mean distances between nests in their study (627 m in 2003 and 150 m in 2004) were somewhat higher than distances reported in the Great Plans and Atlantic populations. Nevertheless, Haffner et al. (2009) concluded that the small home ranges of Great Lakes Piping Plovers demonstrate that even relatively small areas of suitable habitat can have a high conservation value for this species. The four nests in 2017 at the west cell of the Cat Island Chain Restoration Site probably are not a maximum number for this site. Any average inter-nest distance <150 m would allow the configuration of 4 or more nests in the 6-ha sandy island created by dredge spoils in the western Cat Island Chain Restoration Site "cell." Although the number of nesting Piping Plovers may increase by a few pairs in the existing cell, a substantial increase in numbers probably will be best promoted by increasing the total area of sandy substrate available for nesting birds.

Wire nest exclosure surrounding Piping Plover nest during summer 2017. Note growth of new vegetation near this nest. Although the openings are small, adult plovers can easily walk in and out of the exclosure wired slots.

The majority (68%) of successfully breeding adults studied by Haffner et al. (2009) returned to their previous nesting territory from one year to the next, suggesting that the prospects for long-term viability of Piping Plovers at the Cat Island Chain Restoration Site are high. However, almost 64% of the nests studied by Haffner et al. (2009) were destroyed, primarily by fox/skunk predation or human disturbance (40%) or storms (24%). These factors must be acknowledged as potential threats for Piping Plovers at the Cat Island Chain Restoration Site. Access to the nesting area has been restricted by fencing across the only land connection to the Cat Island Chain Restoration Site, yet mink have been observed at the western “cell,” and tracks of other potential mammalian predators have been observed during winter. Avian predators such as Peregrine Falcon (*Falco peregrinus*), gulls, American Crow (*Corvus brachyrhynchos*), and Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*) have been observed regularly at the site. Construction of cages around nests (see image above) will provide important protection of nests, although Murphy et al. (2003) found that predation of adult and fledgling birds increased near cages. Other measures to reduce predation and human disturbance, such as removing predator-attracting perches and reducing vegetation cover (which can provide cover for hunting predators) near nests, will help sustain Piping Plovers at the Cat Island Chain Restoration Site. The presence of fencing across the access road will be particularly important in minimizing access by mammalian predators and humans during the breeding season.

Growth of dense vegetation on the dredge deposits represents another major threat to habitat suitability for Piping Plovers at the Cat Island Chain Restoration Site. Maslo et al. (2011) found that vegetation cover at Piping Plover nest sites should be less than 10% in backshore areas and <13% on dunes. Brudney et al. (2013) reported that distance to woodland was the most important habitat variable associated with nesting success of Great Lakes Piping Plovers. Control of vegetation at the Cat Island Chain Restoration Site will need to be an important element of a long-term adaptive management strategy.

We have assigned a baseline condition of 2.0 for Piping Plovers in the LGB&FR AOC, corresponding to the starting year of our project (2015). Although the species has bred successfully since then, we take a cautious position that the population has not yet established a permanent local breeding population. If multiple pairs continue to nest at the Cat Island Chain Restoration Site, however, this species could be one of the most significant contributors to improved condition of the LGB&FR AOC with respect to fish and wildlife habitat and populations. A condition score of at least 6.0 (Figure 2.13) should be attainable by ensuring that the current population of 4 nesting pairs continues to nest successfully at the site. We propose an ideal condition (score = 10) where at least 10 pairs of Piping Plovers nest in the LGB&FR AOC, with at least one pair nesting somewhere other than the west "cell" of the Cat Island Chain Restoration Site. The conversion curve is nonlinear, where the addition of just a few nests will yield a rapid increase in the score. As the maximum condition is approached, the rate of increase slows.

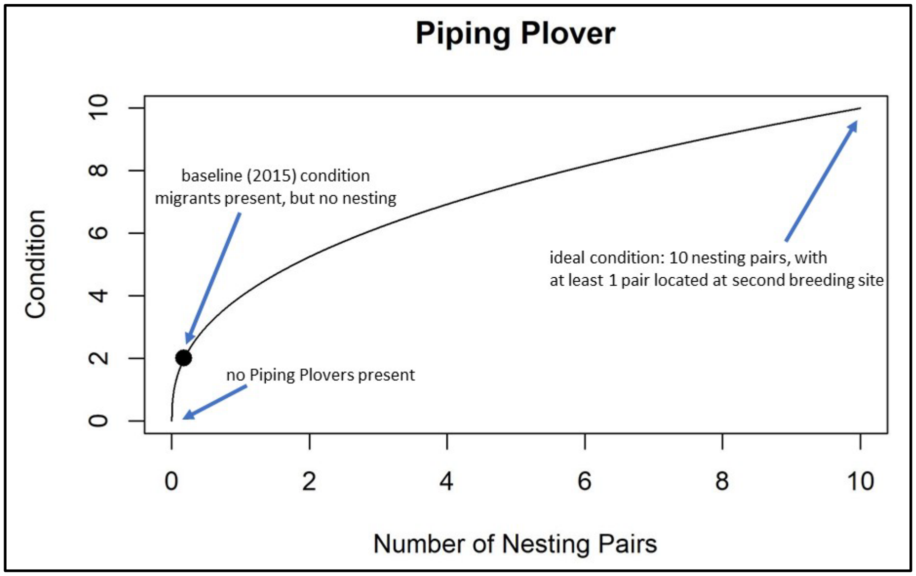


Figure 2.13. Nesting Piping Plover assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the number of nesting pairs (scaled from 0 [no Piping Plovers present] to 10 [ideal condition of 10 nesting pairs at 2 different sites]), which is determined through field surveys. The y-axis is the converted condition for a given IEC score, which ranges from poor condition (0) to good/ideal condition (10).

Shoreline Fish

Smallmouth bass (*Micropterus dolomieu*), Great Lakes (spotted) muskellunge (*Esox masquinongy*), yellow perch (*Perca flavescens*), and three panfish (rock bass, *Ambloplites rupestris*; pumpkinseed, *Lepomis gibbosus*; and bluegill, *Lepomis macrochirus*) are prominent species in the "shoreline fish" group (Table 2.4), which consists of 25 species inhabiting shoreline areas and shallow open water. Most species in this group spawn along vegetated, sandy, or rocky shorelines, although species like spotfin shiner (*Notropis spilopterus*) require other habitats like crevices or bark of submerged logs (Gale and Gale 1977). Many species on this list use tributaries as breeding or nursery habitat, but all of them have been collected along shorelines of the lower bay (Brazner and Beals 1997, Koosmann 2016). We have excluded rare species and regionally introduced species like alewife (*Alosa pseudoharengus*), gizzard shad (*Dorosoma cepedianum*), and common carp (*Cyprinus carpio*), except for the abundant invasive round goby (*Neogobius melanostomus*), which is common in the lower bay and contributes negatively to the status shoreline fish assemblages.

Table 2.4. List of species in the shoreline fish category and their associated statuses. MPCA = Minnesota Pollution Control Agency.

Family	Species	Status
Amiidae	Bowfin (*Amia calva)*	top carnivore (Lyons 1992)
Catostomidae	White sucker (*Catostomus commersonii*)	recommended by S. Hogler (*pers. comm.*)
Centrarchidae	Pumpkinseed (*Lepomis gibbosus*)	intolerant in Ohio (Angermeier and Karr 1986)
Centrarchidae	Bluegill (*Lepomis macrochirus*)	recommended by S. Hogler (*pers. comm.*)
Centrarchidae	Rock bass (*Ambloplites rupestris*)	sensitive (MPCA 2014)
Centrarchidae	Smallmouth bass (*Micropterus dolomieu*)	top carnivore, intolerant (Lyons 1992)
Centrarchidae	White crappie (*Pomoxis annularis*)	top carnivore (Lyons 1992)
Cyprinidae	Carmine shiner (*Notropis percobromus*)	sensitive (MPCA 2014)
Cyprinidae	Common shiner (*Luxilus cornutus*)	lithophilous, insectivorous (Lyons 1992)
Cyprinidae	Emerald shiner (*Notropis atherinoides*)	lithophilous, insectivorous (Lyons 1992)
Cyprinidae	Spottail shiner (*Notropis hudsonius*)	sensitive (MPCA 2014), intolerant (Lyons 1992)
Cyprinidae	Spotfin shiner (*Notropis spilopterus*)	sensitive to development (Brazner and Beals 1997)
Cyprinidae	Bluntnose minnow (*Pimephales notatus*)	recommended for streams by S. Hogler (*pers. comm.*)
Cyprinidae	Fathead minnow (*Pimephales promelas*)	recommended for streams by S. Hogler (*pers. comm.*)
Esocidae	Muskellunge (*Esox masquinongy*)	top carnivore
Esocidae	Northern pike (*Esox lucia*)	top carnivore
Fundulidae	Banded killifish (*Fundulus diaphanus*)	insectivorous (Lyons 1992)
Gobiidae	Round goby (*Neogobius melanostomus*)	undesirable invasive
Lepisosteidae	Shortnose gar (*Lepisosteus platostomus*)	top carnivore (Lyons 1992)
Lotidae	Burbot (*Lota lota*)	top carnivore (Lyons 1992)
Percidae	Johnny darter (*Etheostoma nigrum*)	insectivorous (Lyons 1992)
Percidae	Log perch (*Percina caprodes*)	intolerant, sensitive (MPCA 2014)
Percidae	Walleye (*Sander vitreus*)	top carnivore (Lyons 1992)
Percidae	Yellow perch (*Perca flavescens*)	insectivorous, top carnivore (Lyons 1992)
Percopsidae	Trout perch (*Percopsis omiscomaycus*)	insectivorous (Lyons 1992)

Shoreline fish along sandy beaches are typically distinct from those of coastal wetlands, although the difference is much less pronounced in lower Green Bay than in the middle or upper bay (Brazner and Beals 1997). Even in the upper bay, some shoreline species occur in both sandy beaches and wetlands, so we combine the two groups of shoreline fish for assessment metrics, recognizing that management recommendations will be different for beach vs. wetland shorelines. Brown County records from 1885 describe a wide diversity of native fish in Green Bay, including perch, muskellunge, sunfish, crappies, suckers, catfish, and many others (Smith and Snell 1891, Qualls et al. 2013). Many of the fish species described in this early account are still represented in the LGB&FR AOC, although invasive species and habitat modifications have changed the shoreline fish community irreversibly. Here we describe four native taxa (smallmouth bass, muskellunge, yellow perch, and shoreline/wetland Centrachidae) that have historical, ecological, and economic importance in this ecosystem. Other species included in our assessment metric represent a broader fish diversity in the shoreline zone, in some cases overlapping with species in the tributary fish category.

Turbidity, submerged aquatic vegetation, and substrate conditions all affect the success of shoreline fish. Smallmouth bass inhabit shorelines that have rock, gravel, and submerged logs (S. Hogler, *pers. comm.*, Michigan Department of Natural Resources 2018b). Young fry eat benthic invertebrates, including dreissenid mussels, while adults feed almost exclusively on round gobies (Nelson et al. 2017). Smallmouth bass spawn along shallow shorelines, ~0-2 m deep, that consist of gravel, sand, cobble, bedrock, and logs with little to no vegetation and even near boat docks (Lane et al. 1996, S. Hogler, *pers. comm.*). Adult males build gravel nests along the shoreline near deeper waters for refuge. They guard the nest and young fry for many days after hatching (Michigan Department of Natural Resources 2018b). Like other nearshore breeders, individuals must protect their eggs against round gobies and other potential predators (Qualls et al. 2013). Smallmouth bass use the pelagic zone of the lower bay, including Point Sable and UW-Green Bay campus shoreline, Fox River, and upper Duck Creek (Lower Green Bay and Fox River Area of Concern Biota Database, Wisconsin Department of Natural Resources Fish Mapping Application 2018).

Great Lakes muskellunge, also known as simply muskellunge or Great Lakes/spotted musky, is perhaps the most important game fish in the state. This species was designated the state fish in 1955 (Simonson 2015). Muskellunge can grow to 1.3 m long, weigh up to 31.8 kg, live for over 30 years, and are highly prized by local fishermen (Simonson 2015). Great Lakes muskellunge use open water habitats, including both deep and shallow waters. They are known to use submerged aquatic vegetation, especially several wide-leaved species of native pondweed (*Potamogeton* spp.; Simonson 2015). Individuals prefer clear, less turbid waters for visibility while hunting (Wisconsin Department of Natural Resources Muskellunge Fact Sheet). Adult musky are opportunistic, ambush predators at the top of the food chain. They hide amongst vegetation and rocks waiting for prey, primarily consisting of suckers, yellow perch, and minnows. Individuals also have been reported consuming crappies, ducks, mice, anurans, and even muskrats (Simonson 2015, Wisconsin Department of Natural Resources Muskellunge Fact Sheet). Great Lakes muskellunge spawn along hundreds of meters of shoreline with shallow waters (0-2 m deep) that consists of silt, clay, gravel, and sand with submergent and emergent vegetation (e.g., bulrush) and or woody debris (Lane et al. 1996, Simonson 2015, S. Hogler, *pers. comm.*). They have recently been reported using the Fox River and open water of the lower bay including Dead Horse Bay (Lower Green Bay and Fox River Area of Concern Biota Database, Wisconsin Department of Natural Resources Fish Mapping Application 2018). Since 2000, WDNR's Steve Hogler has conducted musky spawning surveys in the Fox River just north of Voyageur Park and near the railroad bridge, where they are known to spawn (Figure 2.10a).

When Great Lakes water quality declined in the early 1900s due to industrial, urban, and agricultural pollution, populations of native species like lake whitefish, lake trout, and lake sturgeon declined. Yellow perch populations, by contrast, exploded since they are tolerant of poorer water quality, high nutrients, and low oxygen (UW Sea Grant 2013, Wisconsin Department of Natural Resources Yellow Perch Fact Sheet). Yellow perch heavily used the Duck Creek area during the 1970s (Roznik 1979, Herdendorf et al. 1981). Despite their wide tolerance, yellow perch are sensitive to highly degraded water quality and other ecological disruptions; the large populations of the late twentieth century are no longer present today in the LGB&FR AOC. Yellow perch eat zooplankton, minnows, and other small fish, while perch themselves are prey for predatory fish, such as muskellunge, northern pike, and bass (Wisconsin Department of Natural Resources Yellow Perch Fact Sheet). Yellow perch primarily spawn along shorelines in waters ranging from <1 m to >5 m. Spawning areas are characterized by aquatic vegetation, mud, sand, rocks, or woody debris (Lane et al. 1996, S. Hogler, *pers. comm.*). Yellow perch also occur in the pelagic (open water) zone of the lower bay, including Dead Horse Bay, Longtail Point, Point Sable, and UW-Green Bay, and along the Fox River, Duck Creek, and Dutchman Creek (Lower Green Bay and Fox River Area of Concern Biota Database, Wisconsin Department of Natural Resources Fish Mapping Application 2018). As a part of his UW-Green Bay Cofrin Student Research Grant, student David Lawrence discovered that Wequiock Creek, which enters the bay at Point au Sable, provides important nursery habitat for yellow perch. Areas like Wequiock Creek are especially important for yellow perch, because their most critical life stage is when they are juveniles, a life history stage where they need protected streams and open water habitat (Qualls et al. 2013, S. Hogler, *pers. comm.*).

Fish species in the family Centrarchidae are given the name “panfish” because of their relatively small size and ability to fit in a frying pan (up to 20-30 cm in length; Great Lakes Sea Grant Extension Office 2009c). While there is intraspecific variation among the three panfish species of the shoreline fish group, lower Green Bay panfish generally use open water, large rivers, tributaries, and shorelines as adults (S. Hogler, *pers. comm.*). Depending on their age and size, they eat snails, worms, leeches, rotifers, insects, insect larvae, and fish eggs (Great Lakes Sea Grant Extension Office 2009c). Males of rock bass, pumpkinseed, and bluegill build nests, rather than broadcasting or hiding (Lane et al. 1996). Pumpkinseed and bluegill usually build their nests on sandy or gravel substrates near submerged debris, such as fallen trees (NatureServe 2013a,b). Rock bass spawn under rocks or logs in shallow waters (0-2 m deep) with little to no vegetation (Lane et al. 1996). Pumpkinseed also spawn in water 0-2 m deep though they prefer more extensive vegetation. Bluegill spawn in deeper waters, up to 5 m in depth, with extensive submerged or emergent vegetation (Lane et al. 1996). Panfish in the LGB&FR AOC have been found at Dead Horse Bay, the Fox River, Longtail Point, Point au Sable, Dutchman Creek, Duck Creek, Baird’s Creek, the UW-Green Bay Bayshore, and in the pelagic zone of the lower bay (Lower Green Bay and Fox River Area of Concern Biota Database, Wisconsin Department of Natural Resources Fish Mapping Application 2018).

The shoreline fish group includes predatory species that may bioaccumulate environmental contaminants like polychlorinated biphenyls (PCBs), pesticides, and mercury (Northern Pike Fact Sheet, Qualls et al. 2013). Yellow perch, centrarchids, and other shorter-lived fish species are less vulnerable to toxic contaminants, but they require quality shoreline habitat and are affected negatively by habitat degradation and habitat destruction in the coastal zone. Today, species-specific fish advisories based on PCB contamination are regularly posted at boat launches and parks in Green Bay and the Fox River, reflecting both current ecological conditions as well as the legacy effects of toxic contamination during the 1900s. Habitats for many shoreline fish species likewise reflect (often irreversible) legacy effects, but numerous areas (Figure 2.10a) provide opportunities for habitat improvement and restoration in the LGB&FR AOC.

Woody debris and structural diversity along undeveloped shorelines provide microhabitat for spawning and protection of desirable shoreline fish.

The LGB&FR AOC RAP listed species whose populations are no longer self-sustaining in all or part of the AOC because of poor quality spawning habitat, poor water quality, invasive species (e.g., sea lamprey [*Petromyzon marinus*]), or fish passage barriers (Qualls et al. 2013, Wisconsin Department of Natural Resources 2016a). The original RAP stated that the LGB&FR AOC needs to contain "healthy, self-sustaining, naturally reproducing, and diverse populations of native fish species (including …yellow perch … Great Lakes spotted muskellunge, and centrarchids) in abundances sufficient to provide ecological function in the fish community." The RAP also identifies the importance of having quality spawning habitat for fish and a diversity of submerged aquatic vegetation and invertebrates for fish (Wisconsin Department of Natural Resources 2016a).

We assign a baseline condition of 4.0 for this group based tentatively on expert opinion. Shoreline fish in the LGB&FR AOC generally are not doing very well, although this assessment is uncertain due to a lack of quantitative data. Field surveys are needed to adequately assess both baseline condition and future population trends (S. Hogler, *pers. comm.*). Qualls et al. (2013) reported that the overall condition of yellow perch in Green Bay is "mixed" (i.e., "the ecosystem component displays both good and degraded features") with an overall improving trend. Since 1980, the WDNR has conducted trawling surveys in lower Green Bay and has documented fluctuating populations of yellow perch (led by T. Paoli; Qualls et al. 2013). Yellow perch populations declined to the point that commercial fisheries for this species closed in 1995 to allow for population recovery (UW Sea Grant 2013). During the last 15 years, recruitment has been relatively steady, though the long-term outlook is still uncertain (Qualls et al. 2013). While Great Lakes muskellunge were reintroduced successfully to Green Bay in 1989, improvements and continued stocking are still needed (Wisconsin Department of Natural Resources Muskellunge Fact Sheet, Qualls et al. 2013).

Improvements to the ecological condition of shoreline fish may be achieved by 1) protecting and improving long stretches of undeveloped shoreline (e.g., Great Lakes beach) and coastal wetlands for spawning, 2) improving spawning substrate by adding rocky reefs, woody debris, gravel, cobble, etc., 3) restoring or improving submerged aquatic vegetation and emergent marshes, especially those with minimal extent of invasive plants, 4) improving nursery habitat for geographically mobile species like yellow perch, 5) constructing or restoring (if necessary) shallow topographic gradient at edges of small wetlands or shorelines, 6) protecting and enhancing riparian habitats, especially along Duck Creek, Wequiock Creek, and other streams, 7) developing a long-term management plan for sustaining emergent wetland habitat at sensitive wetlands during both high and low water periods, and perhaps most importantly 8) reducing sediment pollution and nutrient runoff.

As with most other multispecies groups, additional work is needed to develop a viable, quantitative metric for assessing the status of shoreline fish in the LGB&FR AOC. Koosmann (2016) used seining to collect from nearshore coastal habitats at the mouths of tributaries using standard nets (16.7-m x 1.8-m net length; 5 mm mesh size) and protocols outlined by Askeyev et al. (2015) and Hahn et al. (2007). We recommend a similar method, emphasizing prescribed, constant effort for each site. Preliminary research is needed to determine the sensitivity of target species (Table 2.4) to a stressor gradient ranging from 0 (worst condition) to 10 (best condition). Initially these may be subjective, but eventually a standard set of objective biotic response curves (see Tributary Fish account below) will permit the calculation of a robust Index of Ecological Condition for nearshore fish assemblages. The average IEC based on presence/absence of nearshore fish species in the 10 best sites (Figure 2.14) will provide a good method for establishing baseline conditions and tracking changes in fish communities in the LGB&FR AOC.

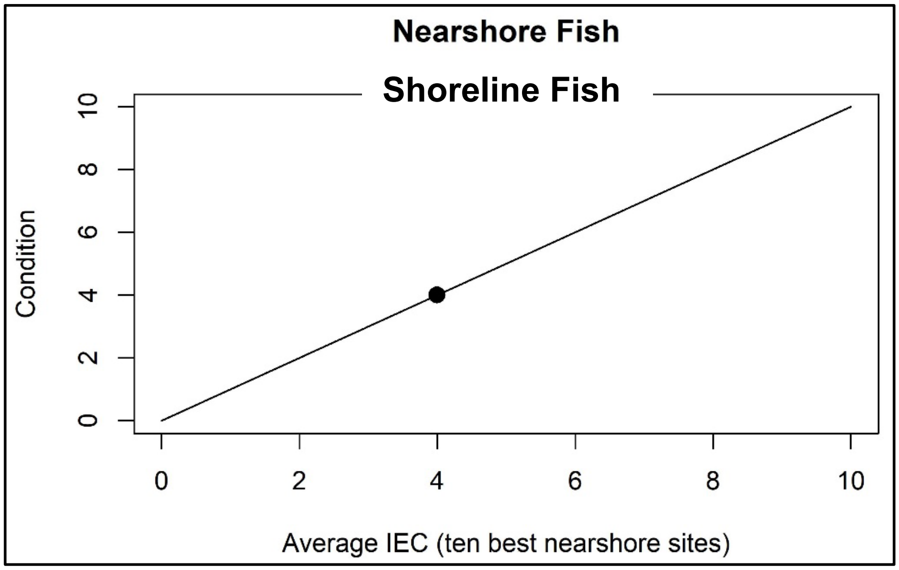
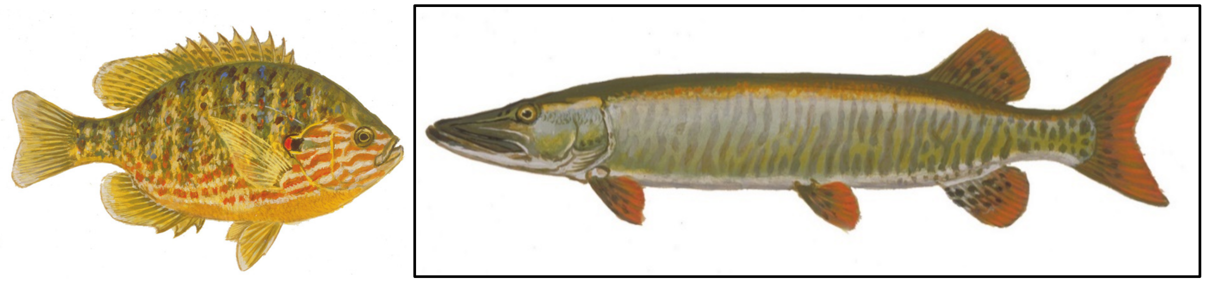


Figure 2.14. Shoreline fish assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the shoreline fish metric (scaled from 0 [worst condition] to 10 [ideal condition]), which is determined through field surveys and application of the Index of Ecological Condition (IEC; Howe et al. 2007). The field metric is the average IEC for the 10 best shoreline/nearshore sites in the LGB&FR AOC.



Shoreline fish: pumpkinseed (left) and muskellunge (right). Illustrations by Virgil Beck from the WDNR Flickr website.

Tributary Fish

Fish species in this category reproduce in small tributaries or use streams as nursery habitat for juveniles. Our preliminary list of tributary fish in the LGB&FR AOC (Table 2.5) includes species that have been recognized as sensitive or pollution intolerant by other studies (Angermeier and Karr 1986, Lyons 1992, Minnesota Pollution Control Agency 2014), top carnivores, stream insectivores, lithophilous stream fishes, and other species recommended by regional biologists (S. Hogler, *pers. comm.*). All species on the list were collected 5 or more times in or at the mouth of Green Bay tributaries by Koosmann (2016).

Table 2.5. List of species in the tributary fish category and their associated statuses. MPCA = Minnesota Pollution Control Agency.

Family	Species	Status
Amiidae	Bowfin (*Amia calva)*	top carnivore (Lyons 1992)
Catostomidae	Golden redhorse (*Moxostoma erythrurum*)	recommended by S. Hogler (*pers. comm.*)
Catostomidae	Greater redhorse (*M. valenciennesi*)	intolerant, sensitive (MPCA 2014)
Catostomidae	Shorthead redhorse (*M. macrolepidotum*)	recommended by S. Hogler (*pers. comm.*)
Catostomidae	Silver redhorse (*M. anisurum*)	recommended by S. Hogler (*pers. comm.*)
Catostomidae	Longnose sucker (*Catostomus catostomus*)	intolerant, sensitive (MPCA 2014)
Catostomidae	White sucker (*Catostomus commersonii*)	recommended by S. Hogler (*pers. comm.*)
Centrarchidae	Pumpkinseed (*Lepomis gibbosus*)	intolerant in Ohio (Angermeier and Karr 1986)
Centrarchidae	Rock bass (*Ambloplites rupestris*)	sensitive (MPCA 2014)
Centrarchidae	Smallmouth bass (*Micropterus dolomieu*)	top carnivore, intolerant (Lyons 1992)
Centrarchidae	White crappie (*Pomoxis annularis*)	top carnivore (Lyons 1992)
Cyprinidae	Carmine shiner (*Notropis percobromus*)	sensitive (MPCA 2014)
Cyprinidae	Common shiner (*Luxilus cornutus*)	lithophilous, insectivorous (Lyons 1992)
Cyprinidae	Longnose dace (*Rhinichthys cataractae*)	intolerant, sensitive (MPCA 2014)
Cyprinidae	Emerald shiner (*Notropis atherinoides*)	lithophilous, insectivorous (Lyons 1992)
Cyprinidae	Northern redbelly dace (*Chrosomus eos*)	sensitive (MPCA 2014)
Cyprinidae	S. redbelly dace (*Phoxinus erythrogaster*)	recommended by S. Hogler (*pers. comm.*)
Cyprinidae	Redside dace (*Clinostomus elongatus*)	intolerant, sensitive (MPCA 2014)
Cyprinidae	Spottail shiner (*Notropis hudsonius*)	sensitive (MPCA 2014), intolerant (Lyons (1992)
Cyprinidae	Bluntnose minnow (*Pimephales notatus*)	recommended by S. Hogler (*pers. comm.*)
Cyprinidae	Brassy minnow (*Hybognathus hankinsoni*)	recommended by S. Hogler (*pers. comm.*)
Cyprinidae	Fathead minnow (*Pimephales promelas*)	recommended by S. Hogler (*pers. comm.*)
Esocidae	Northern pike (*Esox lucia*)	top carnivore
Fundulidae	Banded killifish (*Fundulus diaphanus*)	insectivorous (Lyons 1992)
Gasterosteidae	Brook stickleback (*Culaea inconstans*)	insectivorous (Lyons 1992)
Ictaluridae	Black bullhead (*Ameiurus melas*)	insectivorous (Lyons 1992)
Ictaluridae	Brown bullhead (*Ameiurus nebulosus*)	insectivorous (Lyons 1992)
Ictaluridae	Channel catfish (*Ictalurus punctatus*)	insectivorous (Lyons 1992)
Lepisosteidae	Longnose gar (*Lepisosteus osseus*)	top carnivore (Lyons 1992)
Lepisosteidae	Shortnose gar (*Lepisosteus platostomus*)	top carnivore (Lyons 1992)
Lotidae	Burbot (*Lota lota*)	top carnivore (Lyons 1992)
Percidae	Johnny darter (*Etheostoma nigrum*)	insectivorous (Lyons 1992)
Percidae	Log perch (*Percina caprodes*)	intolerant, sensitive (MPCA 2014)
Percidae	Walleye (*Sander vitreus*)	top carnivore (Lyons 1992)
Percidae	Yellow perch (*Perca flavescens*)	insectivorous, top carnivore (Lyons 1992)
Percopsidae	Trout perch (*Percopsis omiscomaycus*)	insectivorous (Lyons 1992)

Top carnivores and insectivores provide evidence of a healthy food web, while lithophilous ("stone-loving") breeders indicate a quality stream substrate. Intolerant or sensitive species, by definition, are absent or rare in highly polluted streams, so their presence indicates habitat suitability and at least moderate water quality. Many top carnivores like northern pike, walleye, and yellow perch are economically important in addition to their value as ecological indicators. Although adults inhabit open water and shorelines of the lower bay and Fox River, northern pike migrate up small streams, tributaries, and even roadside ditches in early spring to reach inland wetlands that have standing water for spawning. Breeding adults also spawn in Great Lakes coastal wetlands along the bay shoreline (Northern Pike Fact Sheet, Jude and Pappas 1992, Qualls et al. 2013, S. Hogler, *pers. comm.*). Adults are known to travel inland up to 24 km to reach spawning habitat. Pike travel upstream primarily along the west shore and smaller tributaries along the Fox River, including the East River, Dutchman Creek, and Ashwaubenon Creek (S. Hogler and C. Larscheid, *pers. comm.*). After hatching, only about 1% of total fry and fingerling pike survive to adulthood, though the WDNR stocks millions of pike fry and fingerlings across the state (Northern Pike Fact Sheet). Unlike other fish species, northern pike can tolerate low oxygen levels in waterways making them less vulnerable to fish kills. The biggest threat to pike is the destruction of spawning habitat, though the WDNR and others have been actively restoring and improving wetlands and migratory corridors (including removing fish passage barriers) along the west shore of the bay (Qualls et al. 2013).

All four species of redhorse use rivers, streams, and open water as adults and have recently been reported in the lower bay and Fox River (Wisconsin Department of Natural Resources Fish Mapping Application 2018, WDNR Fish Surveys; Figure 2.15). Although individual diets vary slightly, generally redhorses feed on a variety of benthos prey, including insect larvae (e.g., mayflies, caddisflies, midges), mollusks, crustaceans, worms, and copepods, and in some cases plant material (Etnier and Starnes 1993, Great Lakes Sea Grant Extension Office 2009a). The total length of individual species varies, though they can grow to 80 cm (Page and Burr 1991). The presence of most of these species can indicate good water quality (Great Lakes Sea Grant Extension Office 2009a). Redhorse spawn over rock and riffles, so they are good indicators of quality substrate in Green Bay and Fox River tributaries (S. Hogler, *pers. comm.*).

As adults, white and longnose suckers use rivers, shoreline areas, and open water and can grow to 50-63 cm (Michigan Department of Natural Resources 2018a, S. Hogler, *pers. comm.*). Suckers are toothless fish with downward-facing mouthparts that enable them to suck up food along the bottom of a waterbody, hence the name "sucker" (Michigan Department of Natural Resources 2018a, Michigan Sea Grant Suckers Fact Sheet). Like redhorse, they primarily forage on aquatic plants, worms, insect larvae, and algae (Michigan Department of Natural Resources 2018a). In early spring, suckers migrate up both large and small rivers or tributaries and spawn over gravel areas and riffles, though white suckers also spawn in wetlands (S. Hogler, *pers. comm.*, Jude and Pappas 1992). Longnose suckers have recently been reported in the pelagic zone of the lower bay, while white suckers have been reported in Duck Creek, Fox River, East River, Wequiock Creek, Ashwaubenon Creek, Dutchman Creek, and the pelagic zone of the lower bay including near Atkinson, Dead Horse Bay, Long Tail Point, Point Sable, and the UW-Green Bay campus (Lower Green Bay and Fox River Area of Concern Biota Database, Wisconsin Department of Natural Resources Fish Mapping Application 2018).

Eleven species of Cyprinidae (minnows) are a part of the tributary fish species group. These are generally small, narrow toothless fish up to 12 cm in length (University of Michigan Library Digital Collections, Page and Burr 2011), with species-specific diets consisting of algae, insects (e.g., midge larvae), zooplankton, other small invertebrates, or detritus (Etnier and Starnes 1993, Scott and Crossman 1998, Great Lakes Sea Grant Extension Office 2009b). Because minnows are small and often locally abundant, they are important prey for other fish (e.g., brook trout, *Salmo trutta*) and birds (e.g., kingfishers, mergansers; Great Lakes Sea Grant Extension Office 2009b). Minnows typically reproduce in small rivers and protected wetlands (S. Hogler, *pers. comm.*). Bluntnose minnows are capable of withstanding degraded waters (University of Michigan Library Digital Collections), while fathead minnow can survive in waters with low oxygen

(Great Lakes Sea Grant Extension Office 2009b). Both bluntnose and fathead minnows have been frequently detected throughout the LGB&FR AOC, including the Fox River, Wequiock Creek, Duck Creek, Dead Horse Bay, Baird Creek, Dutchman Creek, Ashwaubenon Creek, the lower bay, and other areas (Wisconsin Department of Natural Resources Fish Mapping Application 2018). Brassy minnows have been found in Wequiock Creek, southern redbelly dace has been recorded using the pelagic zone of the lower bay and Duck Creek, and redside dace use the lower bay's pelagic zone, Duck Creek, and Baird Creek (Lower Green Bay and Fox River Area of Concern Biota Database, Wisconsin Department of Natural Resources Fish Mapping Application 2018). Other minnows on the list were collected by Koosmann (2016) in one or more tributaries of Green Bay between the mouth of the Fox River and the Menominee River and Hidden Springs Creek near Ephraim in Door County.

Tributary fish of Green Bay are important links in the bioaccumulation of environmental contaminants such as polychlorinated biphenyls (PCBs), pesticides, and mercury. Top predators such as northern pike and walleye are especially vulnerable to bioaccumulation of these toxins, which can cause reproductive issues or deformities (Qualls et al. 2013). Today, fish advisories based on PCBs are regularly posted at boat launches and parks that provide recommendations on safe fish consumption listed by species (Northern Pike Fact Sheet).

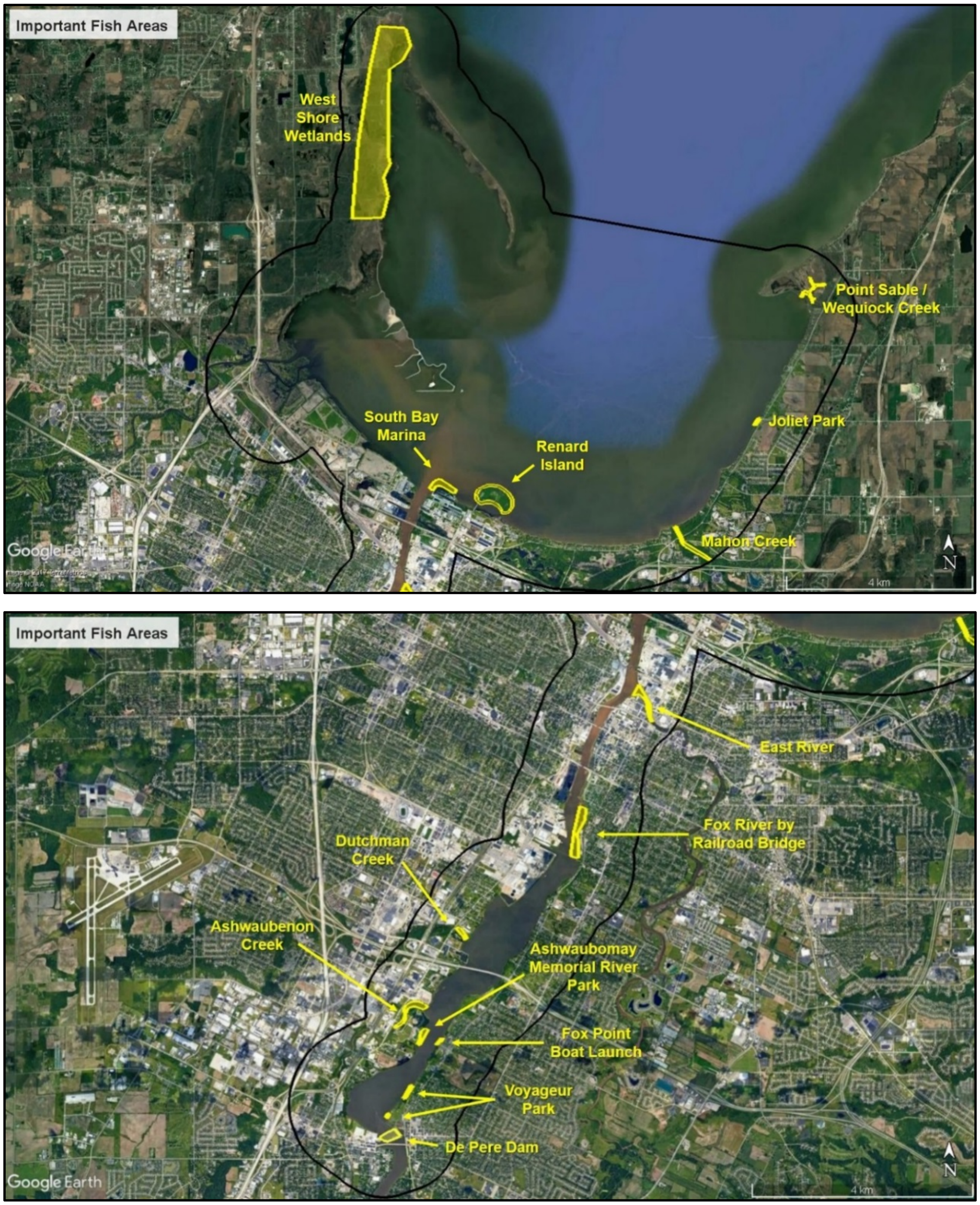


Figure 2.15. Important fish areas in the lower bay (top) and Fox River (bottom) within the Lower Green Bay and Fox River Area of Concern based on Wisconsin Department of Natural Resources records (S. Hogler and C. Larscheid, *pers. comm.*). Map was made using Google Earth Pro software.

Many fish species were originally listed in the RAP because of degraded spawning habitat, poor water quality, high concentrations of pollution/contaminants, invasive species (e.g., sea lamprey [*Petromyzon marinus*]), and fish passage barriers that prevent access to spawning tributaries (Qualls et al. 2013, Wisconsin Department of Natural Resources 2016a). The original RAP states that the LGB&FR AOC needs to contain “healthy, self-sustaining, naturally reproducing, and diverse populations of native fish species (including … northern pike…) in abundances sufficient to provide ecological function in the fish community." Brown County records from 1885 report a wide diversity of native fish, including suckers, perch, catfish, sunfish, and many others (Smith and Snell 1891, Qualls et al. 2013); improved water quality and tributary habitat will help restore some of this original diversity and abundance of fish communities in the LGB&FR AOC.

We assign a baseline condition of 5.0 for this group based on expert opinion, suggesting that tributary fishes are doing modestly well in the LGB&FR AOC (S. Hogler, *pers. comm.*). However, this assessment is based on limited quantitative information, so a more objective assessment mechanism is badly needed. Current research by UW-Green Bay's Dr. Patrick Forsythe and Dr. Christopher Houghton will provide much needed information on fish assemblages of small tributaries connected to Green Bay. Experts believe that populations of northern pike, walleye, and suckers are relatively healthy, while the status of minnows and other groups may be doing the worst in terms of overall condition (S. Hogler, *pers. comm.*). In fact, minnows are more vulnerable or at least uncertain. Redside dace, listed as globally vulnerable (G3G4) and state endangered in Michigan, was not collected by Koosmann (2016) but has been reported in an unpublished management study for Baird Creek, a tributary of the East River, which empties into the lower Fox River in the city of Green Bay (http://dnr.wi.gov/water/wsSWIMSDocument.ashx?documentSeqNo=19205301). Redside dace inhabit substrates of clean gravel, sand, or bedrock in clear, cool headwaters and other streams with high water quality (Tiemann 2012). Several other species of coolwater streams (e.g., white sucker, northern redbelly dace, longnose dace, blacknose dace) were collected by Koosmann (2016), although most species of the lower bay tributaries are typical of warmwater tributaries (Lyons et al. 2009, Lyons 2012).

Improvements to the tributary fish group may be achieved by 1) identifying and removing barriers that provide access to potential spawning areas, 2) improving in-stream microhabitats including gravel riffles, woody debris, and other substrate features, 3) continuing to improve and restore riparian wetlands for spawning of northern pike and other species, 4) reducing sediment pollution, 5) protecting and enhancing riparian buffers, especially along Duck Creek, Wequiock Creek, Mahon Creek, and other permanent streams, and 6) enhancing watershed features that minimize flash flooding and erosion. Only about 12 tributaries flow into the LGB&FR AOC, including Duck Creek, the East River, and 10 smaller watercourses, only about half of which (Wequiock Creek, Mahon Creek, Ashwaubenon Creek, Dutchman's Creek, and an unnamed tributary of Duck Creek) are permanently flowing. The watersheds draining into these tributaries are extensively developed, so improving habitat for tributary fish will be a difficult challenge.

A key element of stream restoration is an accurate assessment of the habitat and fish populations present in the watershed (Lyons and Courtney 1990). Many methods have been proposed for assessing and monitoring fish populations in streams, frequently patterned after the Index of Biotic Integrity (IBI) introduced by Karr (1981) and Angermeier and Karr (1986). Fausch et al. (1984) noted that IBIs (like most biotic indicator metrics) need to be customized to account for regional differences in species composition. Given the highly modified conditions in the LGB&FR AOC and its tributaries, development of a regional assessment metric is especially needed. Traditional IBIs incorporate variables like numbers or percent of individuals in functional groups (e.g., insectivorous cyprinids, intolerant species), often combining species with very different sensitivities to environmental stress. We recommend a more straightforward and objective metric that uses documented responses of all species to environmental condition. The Index of Ecological Condition (IEC; Howe et al. 2007 and subsequent improvements) can be applied with standardized methods that sample only the presence or absence of selected species or the probability of collecting species in multiple samples within the study area (in this case, a stream). Development of a regional IEC requires preliminary work to generate species (biotic) response (BR) functions, which demonstrate the probability of finding a species across a gradient ranging from the worst possible to the best possible environmental condition (Figure 2.16). This might require additional field work, but once parameters of the BR functions have been estimated, then IEC metrics can be generated for new samples based on presence/absence or probability data. The key to generating useful BR functions will be identifying and sampling tributaries that represent a range of underlying condition, from worst possible (IEC = 0) to best possible (IEC = 10). An average IEC from the five best tributaries can then be converted into a score ranging from 0 to 10 and incorporated into the overall AOC Fish and Wildlife Populations BUI assessment (Figure 2.17).

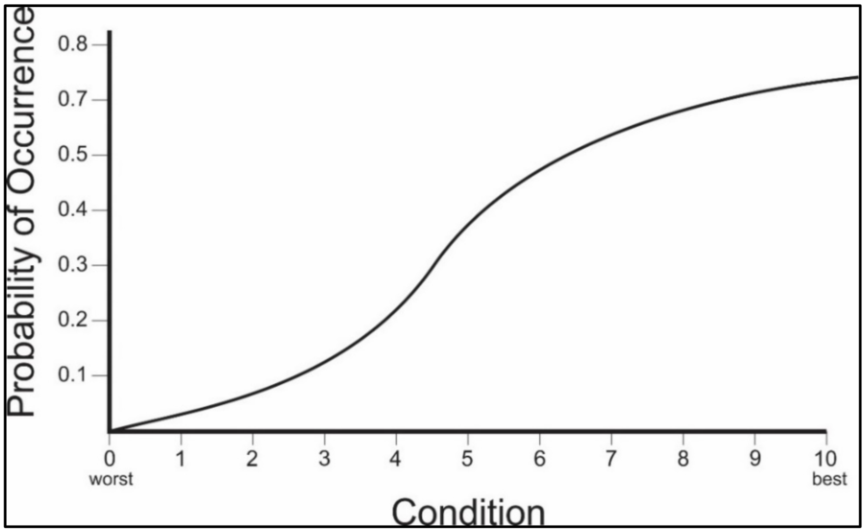


Figure 2.16. Example of a biotic response (BR) function needed for calculation of an Index of Ecological Condition (IEC) for tributary fish. The curve represents the probability of finding a given species (e.g., redbelly dace) in a standard sampling unit (e.g., electrofishing sample in a 100 m stream segment). Once BR functions are estimated for all species of interest, then an IEC can be calculated from new fish samples using the same standard sampling protocol. Measured variables in the new samples may be either probability (from multiple samples over time or at different parts of the stream) or simple presence/absence of each species.

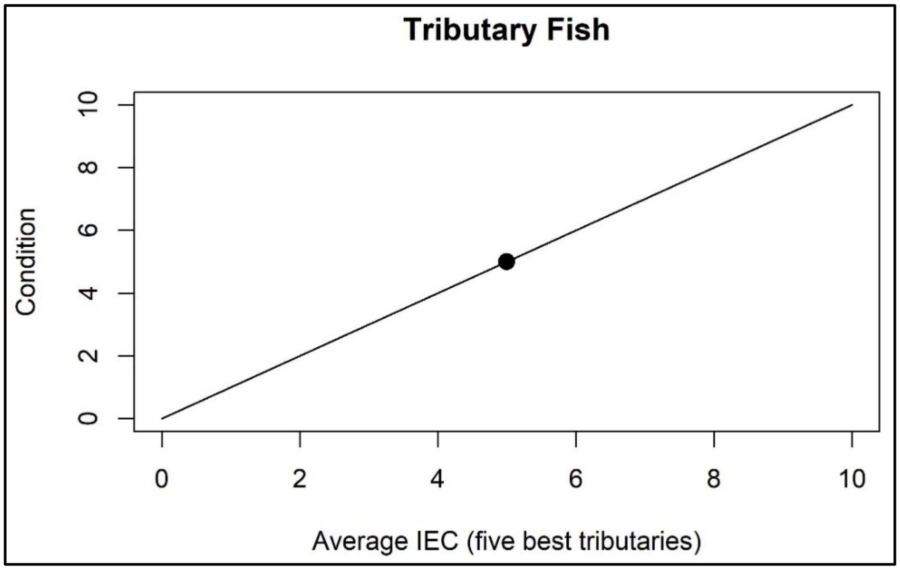


Figure 2.17. Tributary fish assessment for the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC). The x-axis represents the tributary fish metric (scaled from 0 [worst condition] to 10 [ideal condition]), which is determined through field surveys and

application of the Index of Ecological Condition (IEC; Howe et al. 2007). The field metric is the average IEC for the 5 best tributaries in the LGB&FR AOC.

Tributary fish: fish biologist, Rachel Van Dam, holding a northern pike (left; taken by Van Dam's UW-Green Bay northern pike field crew) and fathead minnow (right; taken by Rachel Van Dam)

Wetland Terns

Forster's Tern (*Sterna forsteri*) and Black Tern (*Chlidonias niger*), comprising the "wetland terns" group, are summer resident bird species that breed in wetlands and forage nearby in wetlands and other nearshore habitats, especially emergent/submergent marshes and open water. Threats from habitat loss (e.g., wetland filling, development), invasive species, and bioaccumulation of polychlorinated biphenyls (PCBs) and other toxins have led to both species being listed as state endangered, and Black Tern also is a federal species of concern (Mossman 1989, Qualls et al. 2013). Both species nest in large, extensive emergent marshes (inland and coastal) that are relatively free from human disturbance and human-associated predators (Mossman 1989, McNicholl et al. 2001, Heath et al. 2009). Wetland terns typically build nests on floating mats of dead vegetation in deep water, but individuals also use muskrat lodges and artificial nesting platforms (McNicholl et al. 2001, Heath et al. 2009).

Wetland terns are sensitive to both habitat and water quality stressors. Both species are predators of fish and aquatic macroinvertebrates in the coastal or nearshore environment. These prey items can bioaccumulate environmental contaminants such as pesticides, heavy metals, and PCBs, which are further concentrated in tissues of their predators. Forster's Terns primarily eat small fish, though Black Terns eat odonates, mayflies, crayfish, and small fish (McNicholl et al. 2001, Heath et al. 2009). Harris et al. (1985) and Harris et al. (1993) found that environmental contaminants negatively affected Forster's Terns reproductive success in Green Bay and the Fox River watershed (McNicholl et al. 2001); in addition to direct effects, pesticides may contribute to declines in numbers of Black Terns' preferred invertebrate prey (Heath et al. 2009).

Historically, both wetland terns bred in large numbers in the LGB&FR AOC (Mossman 1989, T. Erdman *pers. comm.*). In fact, the Green Bay Black Tern colony was the largest in the state in the early 1980s (Qualls et al. 2013). Historically, they nested at sites such as the Pulliam Plant/Tank Farm area, Ken Euers Nature Preserve, and Grassy Island (T. Erdman, *pers. comm.*), in addition to a nearby breeding colony in Suamico (Cutright et al. 2006). More recently, Black Terns have declined alarmingly between the 1980s and 2000s (Matteson et al. 2012) and no longer nest regularly in the LGB&FR AOC. Despite the WDNR's efforts to install artificial nesting platforms for Black Terns at Dead Horse Bay/Longtail Point in 2017, no nests or recently fledged young have been found within the past few years; however, biologists witnessed agitated behavior of Black Terns (i.e., adults aggressively diving at biologists) at Dead Horse Bay/Longtail Point in 2016 and 2017 (eBird 2017); agitated tern behavior can signify that a nest or young is nearby, though it is not enough evidence to confirm breeding activity.

During the late 1960s through late 1980s, Forster's Terns nested at several locations in lower Green Bay, including Point au Sable, Duck Creek Delta, Longtail Point, Renard Island (formerly known as "Kidney Island"), Pulliam Plant/Tank Farm area, Ken Euers Nature Preserve, and Sensiba State Wildlife Area just north of Longtail Point, but outside of LGB&FR AOC study area (Mossman 1989, T. Erdman, *pers. comm.*). According to records from the first Wisconsin Breeding Bird Atlas Project (WBBA), Forster's Terns bred in the LGB&FR AOC between 1995 and 1997 (eBird 2017). The WDNR recently installed artificial nesting platforms for Forster's Terns in the LGB&FR AOC (Figure 2.18). These have been used successfully by Forster's Terns in 2017 near the Cat Island Chain Restoration Site (2015 only), Duck Creek Delta, and Dead Horse Bay/Longtail Point (Figure 2.18; J. Martinez, *pers. comm.*). For now, the WDNR will continue maintaining the Duck Creek and Dead Horse Bay nesting structures, though not the one at the Cat Island Chain Restoration Site, where the platform was converted in 2017 for Common Tern (*Sterna hirundo*) usage (J. Martinez, *pers. comm.*).

Figure 2.18. General known locations of current Forster's Tern nest locations within the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC) based on WDNR records (J. Martinez, *pers. comm.*) and the Wisconsin Breeding Bird Atlas 2 Project (eBird 2017). The Cat Island Chain Restoration Site's (2015) artificial nesting site is no longer being maintained but instead was converted to Common Tern nesting structures. Map was made using Google Earth Pro software.

We assign a baseline condition of only 3.0 for this group given the absence of nesting Black Terns and presence of just two small colonies of Forster's Terns. Our recommended optimal condition for wetland terns in the LGB&FR AOC is 10 or more local breeding colonies separated by at least 500 m from one another (Figure 2.19). Improvements may be achieved by continuing to maintain existing artificial nesting structures in the Duck Creek Delta and Dead Horse

Bay/Longtail Point and creating additional structures if possible, particularly for Black Terns. Establish colonies at other locations, such as Point Sable at Peters Marsh, by installing additional platforms. Controlling undesirable invasive plant species, such as *Phragmites*, enhancing emergent/submergent marsh to improve food sources, maintaining pockets of open water, and minimizing human disturbance during the nesting season would improve wetland tern nesting habitat. During low water years, ensure that local refugia are available for appropriate nesting habitat (e.g., deep water emergent marsh), such as at the diked Sensiba SWA, or other nearby inland wetlands (Gnass Giese et al. 2018) because low waters may increase egg predation (Heath et al. 2009).

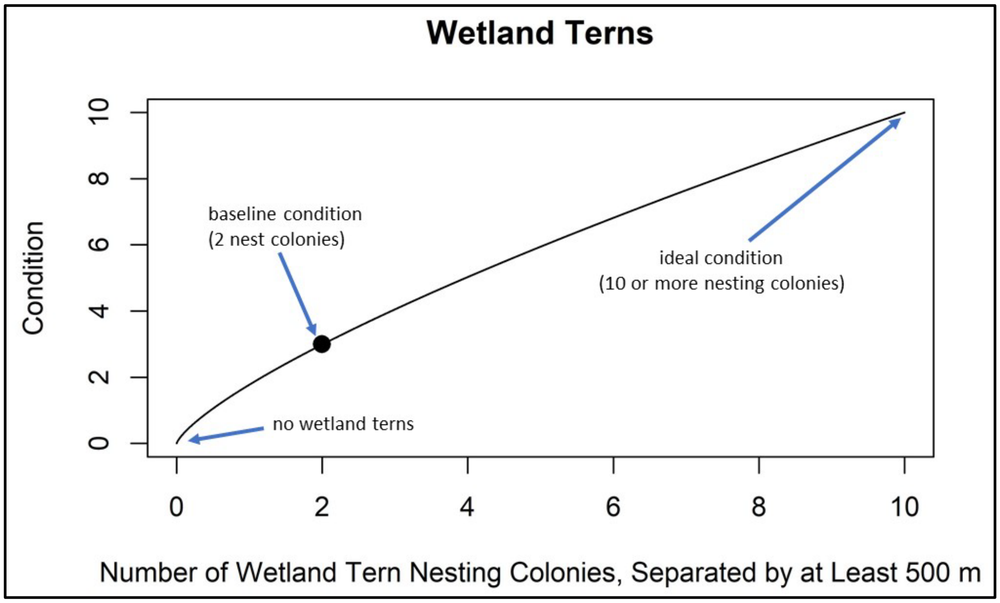


Figure 2.19. Wetland terns (only Black and Forster's Terns) assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the wetland tern metric, i.e., number of wetland tern nesting colonies, (scaled from 0 [no wetland terns] to 10 [10 or more nesting colonies]), which is determined through field surveys, and the y-axis is the converted condition for a given wetland tern metric score, which ranges from poor condition (0) to good/ideal condition (10).

Wetland terns: Forster's Terns (left) and Black Tern (right). Photographs taken by Thomas Prestby.

Anurans

The “anurans” species group consists of seven frog and one toad species: American toad (*Bufo americanus*), American bullfrog (*Lithobates catesbeianus*), green frog (*Lithobates clamitans*), Cope’s gray treefrog (*Hyla chrysoscelis*), eastern gray treefrog (*Hyla versicolor*), northern leopard frog (*Lithobates pipiens*), spring peeper (*Pseudacris crucifer*), and wood frog (*Lithobates sylvaticus*). All 8 species have been documented recently in the LGB&FR AOC by the Great Lakes Coastal Wetland Monitoring Program (CWMP, 2011-2017; Uzarski et al. 2017) and additional field surveys conducted for this project in 2015. These records include audio recordings archived at the UW-Green Bay’s Cofrin Center for Biodiversity. According to 1981-1995 data collected for the Wisconsin Frog and Toad Survey, pickerel frog (*Lithobates palustris*) and boreal/western chorus frog (*Pseudacris maculate/triseriata*) both were reported at two locations in Brown County, Wisconsin (Mossman et al. 1998). Other Great Lakes anuran species not present in the LGB&FR AOC include Fowler’s toad (*Anaxyrus fowleri*), which occurs in southern/eastern Great Lakes states, Blanchard’s cricket frog (*Acris crepitans*), found primarily in southern Wisconsin, and mink frog (*Lithobates septentrionalis*), which mostly occurs in northern Wisconsin (Wisconsin Herp Atlas Project 2007). To our knowledge, none of these three species have ever been detected in the LGB&FR AOC.

Within the LGB&FR AOC, anurans use a variety of habitats during the breeding and post-breeding seasons. We formally summarized CWMP and LGB&FR AOC anuran survey data from 2011 to 2015 in Great Lakes coastal wetlands and inland marshes and investigated anuran habitat use and occurrences in the LGB&FR AOC (Otto et al. 2017). During the breeding season, not surprisingly, most anurans tended to occur near emergent marshes, open water, and wet forests (Figure 2.20). Anuran species diversity was the highest along the lower bay’s west shore with few to no anurans found along the heavily developed Fox River (Figure 2.21). Green frogs tended to occur most commonly along the east shore, while American toads were more common along the west shore (Figure 2.21). A comprehensive analysis of anuran communities in the bay of Green Bay’s Great Lakes coastal wetlands and the response of these communities to changing water levels can be found in Gnass Giese et al. (2018) using CWMP 2011-2017 data. We found that green frogs tended to occur along the eastern shore in the middle and upper regions of the bay, while northern leopard frogs and spring peepers were more frequently detected along the west shore (Gnass Giese et al. 2018). However, the LGB&FR AOC supported fewer anurans compared to wetlands of the middle and upper bay (Gnass Giese et al. 2018), likely because habitats in the more urbanized lower bay are degraded by invasive species, shoreline degradation, and water pollution. Gray treefrog (eastern and Cope’s combined) and American toad were the most frequently detected anuran species in the LGB&FR AOC based on 2011-2017 CWMP field data.

Like many plants and animals, anurans are affected by both short-term (daily seiches) and long-term changes in water levels, at least in coastal emergent marshes (Gnass Giese et al. 2018). Generally, more anuran species and individuals are present during periods of higher lake levels; American bullfrog, green frog, northern leopard frog, and wood frog are positively associated with higher waters, while American toad is the only local species that is negatively associated with water levels (Gnass Giese et al. 2018). American bullfrogs are more abundant in LGB&FR AOC coastal wetlands than in wetlands farther north in Green Bay, unlike the other anurans that are more abundant in the middle and upper bay wetlands (2011-2017 data).

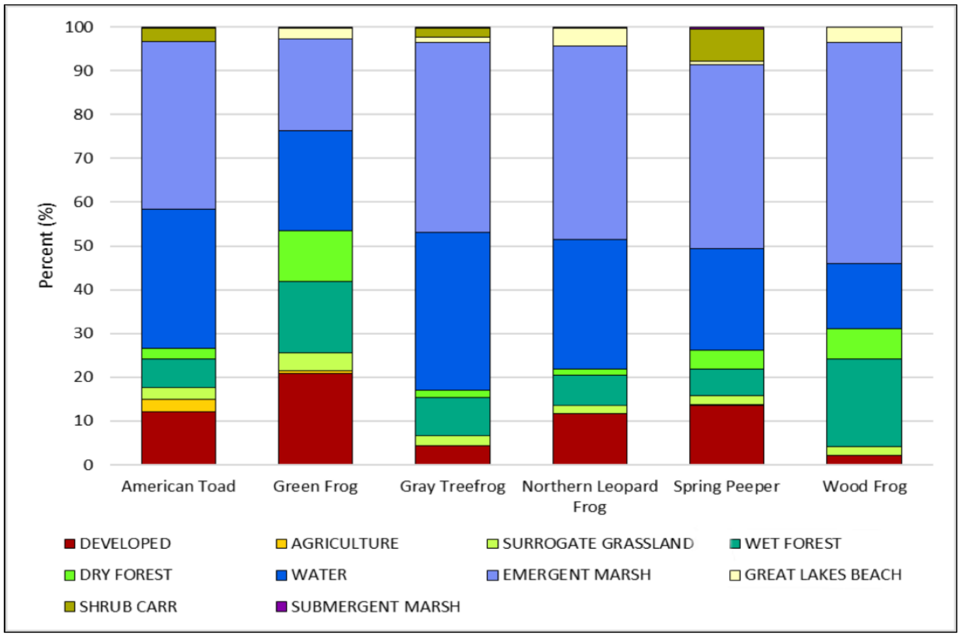


Figure 2.20. Percent habitat used by anuran species within 200-m circular buffers of 32 point count locations in the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC). American bullfrog was excluded because it was only detected at two points. Cope's gray and eastern gray treefrog detections were combined. Habitats were delineated throughout the LGB&FR AOC during July 2015. This bar chart was created by Maria Otto and presented in Otto et al. (2017).

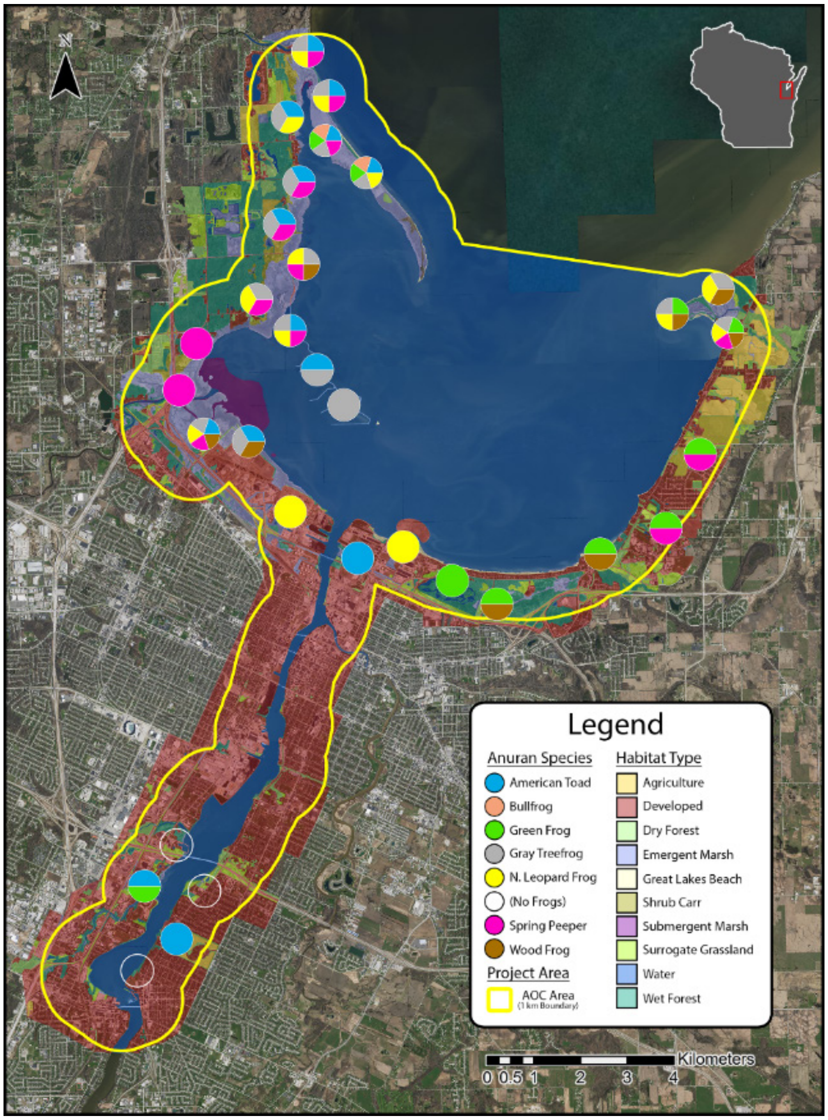


Figure 2.21. Anuran point count locations (n = 32) from Great Lakes Coastal Wetland Monitoring Program (CWMP; 2011-2015) and LGB&FR AOC surveys (2015). Anuran species composition is illustrated in pie charts centered over the survey locations. Note that some CWMP survey locations (e.g., Point Sable) were sampled over multiple years, so a single year was randomly selected and subsequently displayed here. This is relevant because American toad has been reported at Point Sable on the east shore during surveys in other years. Habitats were mapped by field crews in July 2015 within a 1-km buffer of the Lower Green Bay and Fox River Area of Concern (yellow line) and later digitized into polygons by Jesse Weinzinger and Michael Stiefvater. Map was created by Jordan Marty using ArcMap 10.3.1 (Environmental Systems Research Institute 2015) and displays Brown County Land Information Office's digital orthophotos from spring 2014 (used with permission). This map was presented in Otto et al. (2017).

Little historical information about anurans in the LGB&FR AOC has been formally summarized; however, because emergent marshes and other coastal habitats historically were much more widespread in lower Green Bay (Bosley 1978), overall abundance and diversity of anurans almost certainly have decreased significantly during the last century. Historical Brown County air photos (e.g., 1938 and 1960, Brown County Planning and Land Services, https://browncounty.maps.arcgis.com/apps/webappviewer/index.html?id=61fba3fd419045e48aa6ba759838387c) show extensive emergent/submergent marshes in the Duck Creek Delta, Dead Horse Bay/Longtail Point, Peters Marsh, and along the western side of the Fox River by the De Pere Dam. The destruction and fragmentation of the coastal zone of lower Green Bay is already visible in the 1938, and wetland destruction continued through 1960 and later air photos. The long-term Wisconsin Frog and Toad Survey began in 1981 in response to noticeable declines of species such as northern leopard frog and American bullfrog (Mossman et al. 1998). Between 1981 and 1995, pickerel frog and chorus frog were both reported in two locations in Brown County, Wisconsin (Mossman et al. 1998), but neither species has been reported recently despite multiple survey efforts in the LGB&FR AOC (e.g., CWMP; Uzarski et al. 2017). Statewide since the 1980s, northern leopard frog and American toad populations have been declining (Kitchell et al. 2016). Other than results from the Wisconsin Frog and Toad Survey and the Wisconsin Herpetological Atlas, the most significant historical account of anurans in Green Bay described an outbreak of at least 175 million northern leopard frogs over just two days in local marshes of Oconto during the summer of 1952 (Waldron 1953). The lower bay was almost certainly very productive as well during this time.

Anurans are important because they prey on aquatic species, including insects and other invertebrates that depend on the coastal or nearshore environment. These critical coastal areas in lower Green Bay are vulnerable to environmental contaminants such as pesticides, heavy metals, and polychlorinated biphenyls (PCBs; Qualls et al. 2013). It is well documented that anurans are highly sensitive to toxins and, if exposed in large amounts, can result in deformities and reproductive issues (Kersten 1997, Rosenshield et al. 1999, Qualls et al. 2013). Out of the eight anurans reported in the LGB&FR AOC, American bullfrog and northern leopard frog are listed as state special concern species, though American bullfrog is also state ranked as "vulnerable" (S3). The original RAP stated that the LGB&FR AOC needs to contain "healthy, self-sustaining, naturally reproducing, and diverse populations of…amphibians (including spring peepers, leopard frogs, American toads, eastern gray tree frogs, green frogs, bullfrogs, and salamanders)" (Wisconsin Department of Natural Resources 2016a), which was clearly necessary due to the significant loss of marshes for this group to breed.

We recommend a multispecies Index of Ecological Condition (Howe et al. 2007) for tracking the condition of anurans in the LGB&FR AOC based on species biotic response (BR) curves (e.g., Figure 2.22) developed for the Great Lakes Coastal Wetland Monitoring Program (Uzarski et al. 2017). Because this multispecies metric is already standardized on a 0-10 scale, no conversion curve is necessary, although benchmarks can be visualized on a linear regression of the multispecies IEC metric and current condition (Figure 2.23). The IEC value for 5 high quality wetland complexes in the LGB&FR AOC exceeds 8.0, but we propose a target value that averages IECs from the 10 best wetlands, defined as wetland complexes separated by at least 500 m from other wetland sites. The current condition for 10 monitored wetlands is approximately 7.0 (Figure 2.23). In other words, anurans currently are doing well in the LGB&FR AOC, despite significant losses of historical wetland habitat (Bosley 1978). Many remaining marshes are dominated by aggressive, invasive plant species, especially common reed (*Phragmites australis*) and hybrid cattail (*Typha* × *glauca*). Almost all riparian wetlands along the Fox River have been destroyed, and water quality is degraded throughout the AOC. Improved wetland habitat at existing high-quality sites like Deadhorse Bay, Longtail Point, Peter's Marsh, and Point au Sable will be difficult, so progress toward the target IEC average will be most cost effective by improving conditions in 5-6 other wetland complexes. Specific measures include improving local water quality, controlling invasive species, and perhaps minimizing road kills by establishing safe road crossings for anurans in strategic locations. Because different anuran species thrive during varying water levels (Gnass Giese et al. 2018), a long-term management plan for sustaining emergent wetland habitat at sensitive wetlands during both high and low water periods is needed. Existing southern sedge meadow remnants (e.g., Malchow-Olson Tract, Point au Sable) provide excellent opportunities for expanding amphibian habitat, although invasives must be controlled and replaced with native vegetation.

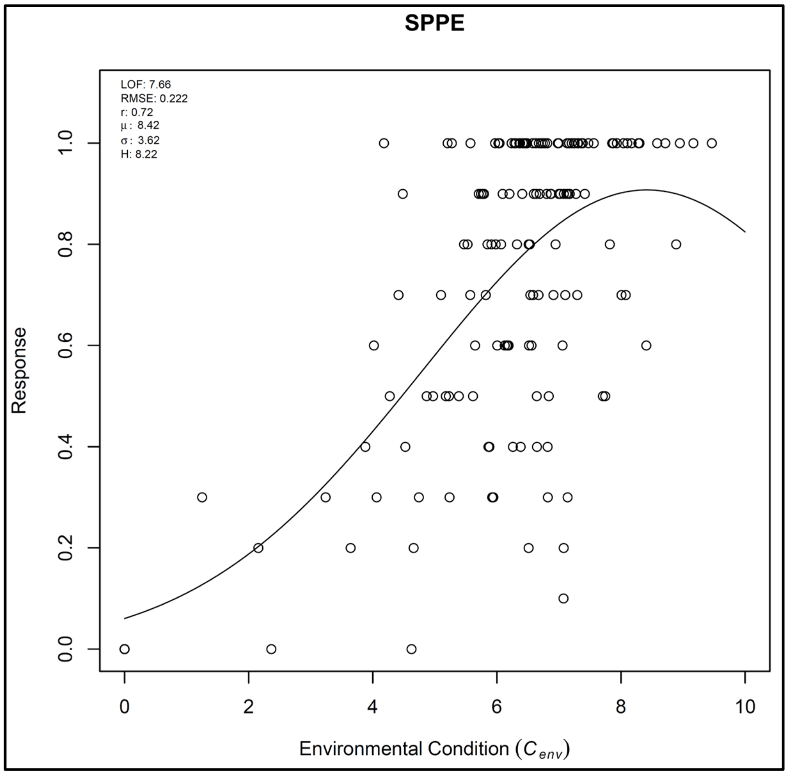


Figure 2.22. Species biotic response curve for spring peeper (SPPE), a frog, based on occurrences in 1,460 point counts collected between 2003 and 2017 at coastal wetlands across the Laurentian Great Lakes by the Great Lakes Coastal Wetland Monitoring Program (Uzarski et al. 2017) and the Great Lakes Environmental Indicators Project (Price et al. 2007). Response (y-axis) is the probability of occurrence or frequency in sets of 10 points "binned" according to their similarity in C_{env} (x-axis), an independent measure of environmental condition describing the "human footprint" at and surrounding the sample location.

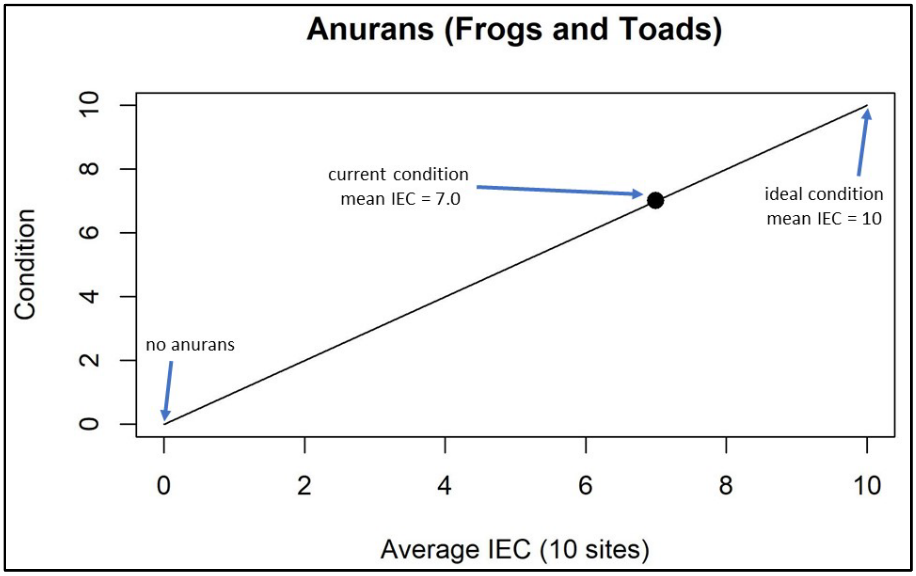


Figure 2.23. Anurans (frogs and toads) assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the anuran metric (scaled from 0 [no anurans] to 10 [ideal anuran assemblage/quality]), which is determined through field surveys and application of the Index of Ecological Condition (IEC; Howe et al. 2007). The field metric is the average IEC for the 10 best wetland sites in the LGB&FR AOC. These sites may change from year to year depending on anuran occurrences.

Anurans (left to right): northern leopard frog, American toad, and gray treefrog. Photographs taken by Robert Howe.

Bald Eagle (winter)

When open water is available, lower Green Bay and the Fox River attract large numbers of waterfowl, gulls, and other winter birds, including Bald Eagles (*Haliaeetus leucocephalus*). These numbers are highly variable and unpredictable, however. During the heart of cold winters, open water is present only at the mouth of the Fox River adjacent to the Pulliam Power Plant and at the De Pere Dam. Small numbers of eagles - or no eagles at all - may be found during a given visit to these areas. At other times, wintering Bald Eagles in the AOC can number 40 or more.

In addition to ice conditions, the overall status of Bald Eagles in Wisconsin and the western Great Lakes region affects the maximum number of eagles that can be expected in the LGB&FR AOC. Regional abundances of wintering Bald Eagles are recorded by Wisconsin's annual Midwinter Bald Eagle Survey, conducted in conjunction with the winter waterfowl surveys by Wisconsin DNR field staff, landowners, and volunteers (Wisconsin Department of Natural Resources 2017). During a prescribed period (in 2017, 4-18 January), observers count the number of Bald Eagles observed on specific routes conducted by plane, vehicle, boat, and on foot. In 2017, 48 midwinter Bald Eagle survey routes yielded 481 Bald Eagles, a 27% decrease compared with the 2016 count. This decrease was largely attributed to snow and ice conditions, given that over-wintering eagles are less likely to concentrate at traditional feeding and roosting areas when large areas of open water are available. The overall numbers of nesting Bald Eagles has increased steadily since the 1970s, including an increase of 5.7% (86 nests) between 2016 and 2017. Brown County was home to only 9 of the 1,590 occupied eagle nests in Wisconsin during 2017 (Wisconsin Department of Natural Resources 2017), so wintering eagles obviously come from elsewhere, most likely from northern Wisconsin and Michigan's Upper Peninsula.

By far the largest numbers of winter Bald Eagle sightings are reported from two localities, the mouth of the Fox River and the Cat Island Chain Restoration Site. Smaller numbers are observed from Point au Sable, Bay Beach Wildlife Sanctuary, Ken Euers Wetland Preserve, and the De Pere Dam and Voyager Park. Accessibility of open water is doubtlessly responsible for this pattern; many eagles rest or feed on ice at the edge of open water, typically seen from these two important vantage points. Two factors attract wintering Bald Eagles: 1) an accessible supply of food and 2) safe roosting sites (Sabine and Klimstra 1985). Buehler et al. (1991) observed that eagles near Chesapeake Bay in the eastern U.S. are more likely to roost communally in fall and winter, especially at sites with large trees and protection from cold northerly winds. Individuals also strongly preferred large (>40 ha) woodlots and avoided roosts near human developments. In northwestern Washington, Stalmaster and Gessaman (1984) reported a preference of wintering eagles for large conifers, which provided energy savings due to the more protected microclimate. Energy is lost when eagles are disturbed by human activity; Stalmaster and Newman (1978) and Stalmaster and Kaiser (1998) found that recreational activities negatively affected wintering eagles in Washington.

Bald Eagles are affected by environmental toxins (Best et al. 1994, Bowerman et al. 1995, Clark et al. 1998, and others) and hence are important indicators of environmental health. We assigned a weighting of 12 (midpoint value) for wintering eagles; although they are likely excellent indicators, numbers of wintering birds are influenced by many factors (ice conditions, regional breeding population, etc.) that cannot be controlled by actions within the LGB&FR AOC. Current condition is assigned a value of 7.0. Daily numbers of Bald Eagles from November to March are frequently more than 20 according to records contributed by citizen scientists to the online bird record repository, eBird (Sullivan et al. 2009). Continuous daily or even weekly monitoring of Bald Eagles in the LGB&FR AOC would be expensive, so we recommend using eBird as a resource for assessing the annual condition of wintering Bald Eagles in the study area. Since 2012, the number of days from November to mid-March when the number of reported Bald Eagles was 20 or more has ranged from 5 to 12. We suggest that an ideal condition would be when the number of days with 20 or more eagles in the AOC exceeds 15 (Figure 2.24). Even if this number were to be achieved by simply improved reporting, the maximum score of 10 could be justified because the health of wintering Bald Eagles in lower Green Bay and the Fox River would be well established and monitored, both highly desirable conditions.

Management measures to increase numbers of wintering Bald Eagles would be to identify and improve roosting areas for eagles near open water areas and to maintain healthy fish populations in the lower bay and Fox River. Protection of large conifers in large woodlands near the bay in places like Point au Sable, Barkhausen Nature Preserve, and other sites where human disturbance is minimal likely will help achieve the optimal condition of 20 or more wintering Bald Eagles in the LGB&FR AOC.

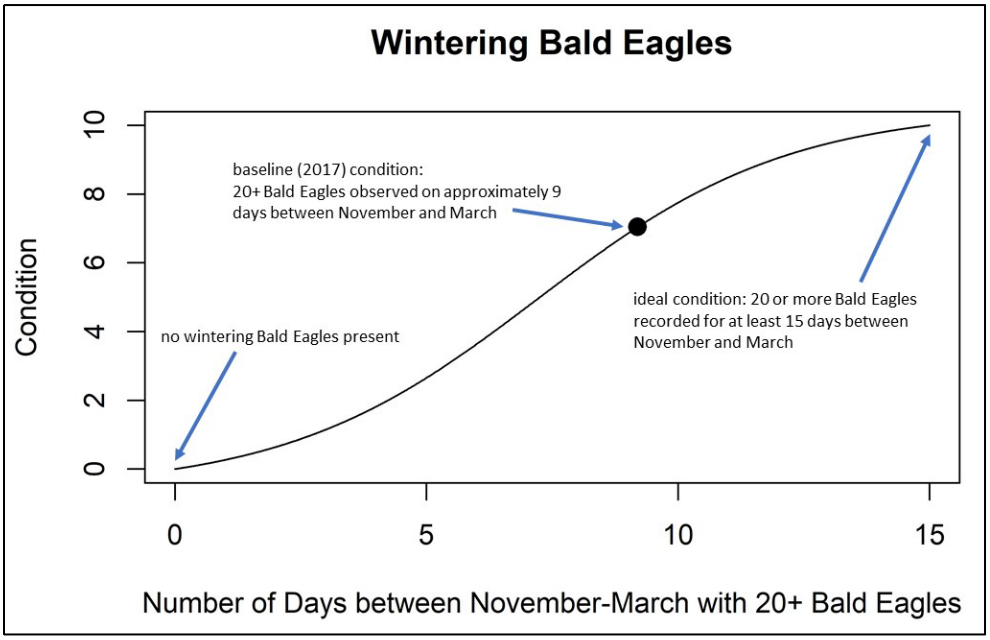


Figure 2.24. Wintering Bald Eagle assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the number of days where there are 20+ Bald Eagles (scaled from 0 [no eagles] to 10 [ideal condition]), which is determined through field surveys. The y-axis is the converted condition, which ranges from poor condition (0) to good/ideal condition (10).

Wintering Bald Eagles in the LGB&FR AOC are often observed on ice along areas of open water. Photo on left from the Creative Commons (http://jooinn.com/bald-eagle-fishing.html?ref=2296). Photo on right courtesy of Thomas Prestby.

Marsh Breeding Birds

The "marsh breeding birds" group consists of birds regularly encountered in emergent marshes, including marsh-obligates and several marsh-users, but excluding wetland-breeding terns (e.g., Black Tern [*Chlidonias niger*]) and other species (e.g., coastal bird [breeding season], Osprey), which are treated separately. A marsh-obligate is a bird species that only breeds and lives in open marshes and not any other habitat, including species such as American Coot (*Fulica americana*), Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*), Virginia Rail (*Rallus limicola*), Marsh Wren (*Cistothorus palustris*), Least Bittern (*Ixobrychus exilis*), and others. In contrast, a marsh-user is a species that may use marshes for foraging and breeding but does not necessarily require open, emergent marshes for breeding (e.g., Common Yellowthroat [*Geothlypis trichas*], Red-winged Blackbird [*Agelaius phoeniceus*], Song Sparrow [*Melospiza melodia*], Blue-winged Teal [*Anas discors*], and others. Common Yellowthoat, for example, will breed in open wetlands, grassy areas, shrub carr, and forests (Guzy and Ritchison 1999).

Within the LGB&FR AOC, marsh breeding birds use high energy coastal, inland, riparian, and roadside emergent marshes, though some bird species are more sensitive to disturbed marsh areas than others (Howe et al. 2007, Gnass Giese et al. 2018). Sandhill Crane (*Grus canadensis*) and Swamp Sparrow (*Melospiza georgiana*), for example, tend to be found in higher quality emergent marshes (Howe et al. 2007); whereas, Red-winged Blackbirds are known to breed in heavily disturbed, emergent roadside marshes along major highways and interstates (Wisconsin Breeding Bird Atlas 2 Project; eBird 2017).

Different marsh breeding bird species utilize a variety of local habitats within emergent marshes. For example, Yellow-headed Blackbirds build nests over water in wetter habitats, such as cattail-dominated (*Typha* spp.) marshes, while American Bitterns (*Botaurus lentiginosus*) nest in drier habitats like grassy emergent plants (Twedt and Crawford 1995, Lowther et al. 2009, Gnass Giese et al. 2018). Still others (e.g., American Coot) nest on floating mats of dead vegetation (Brisbin Jr. and Mowbray 2002). The marsh breeding bird group is also highly affected by changing water levels in the Great Lakes, at least in coastal emergent marshes, which are affected by seiche and storms (Timmermans et al. 2008, Gnass Giese et al. 2018). Species, such as Sandhill Crane, Swamp Sparrow, and Sedge Wren (*Cistothorus platensis*), are associated with lower water levels, while, Marsh Wren, Pied-billed Grebe (*Podilymbus podiceps*), Sora (*Porzana* *carolina*), and American Coot are more commonly found during higher lake levels (Timmermans et al. 2008, Gnass Giese et al. 2018). Generally, more bird species are present in Green Bay emergent marshes during higher water levels, perhaps due to the more favorable ratio of open water to emergent marsh vegetation (Gnass Giese et al. 2018).

Historically, the most common marsh-breeding waterfowl and waterbirds in lower Green Bay included Blue-winged Teal, Pied-billed Grebe, Gadwall (*Anas strepera*), and Mallard (*Anas platyrhynchos*; T. Erdman, *pers. comm.*). Extensive emergent/submergent marshes occurred in the Duck Creek Delta, Dead Horse Bay/Longtail Point, Peters Marsh, and along the western side of the Fox River by the De Pere Dam. These habitats are clearly visible in the 1938 and 1960 air photos provided by Brown County, and earlier historical accounts and drawings portray even more extensive wetlands near the mouth of the Fox River and elsewhere in the LGB&FR AOC. The marsh by the De Pere Dam contained submergent marsh and cattail beds, including floating mats, which were heavily used by marsh breeding birds such as Least Bittern, Blue-winged Teal, Marsh Wren, and rails (T. Erdman, *pers. comm.*). According to Harris and Cook (1973) in the 1970s, Peters Marsh provided critical habitat for many marsh breeding birds, some of which are rare or absent today, including Yellow-headed Blackbird, Mallard, Northern Pintail (*Anas acuta*), Gadwall, teal, American Coot, Common Gallinule (*Gallinula galeata*), Least Bittern, Sora, King Rail (*Rallus elegans*; no recent breeding records), Virginia Rail, Wilson's Snipe (*Gallinago delicata*), Marsh Wren, and others.

According to our observations and 2014-2017 data from the Wisconsin Breeding Bird Atlas 2 and local experts (e.g., T. Prestby, *pers. comm.*), many important marsh breeding birds currently nest in the LGB&FR AOC, especially at Peters Marsh, the Duck Creek area, Dead Horse Bay / Longtail Point, and Point Sable (Table 2.6). Multiple records of Sandhill Crane, Yellow-headed Blackbird, and American Coot breeding in the LGB&FR AOC have been confirmed, but only one recent breeding record has been confirmed for American Bittern, Gadwall (which was abundant historically), Least Bittern, and Virginia Rail (eBird 2017). Presently, no breeding records have been documented for Sedge Wren and Wilson's Snipe, although observers have reported several "probable" breeding records, where an observer witnessed an adult being agitated (perhaps near a nest or young) or giving a courtship display (eBird 2017). The absence of Sedge Wren breeding records is significant, though not surprising, since less than 1 ha of southern sedge meadow habitat remains within 1 km inland of the LGB&FR AOC boundary. At well over 20-30 locations, common marsh-users, such as Red-winged Blackbird and Mallard, have been regularly reported breeding in the LGB&FR AOC (eBird 2017). Undoubtedly more breeding records will be noted in the LGB&FR AOC during the remaining two years of the Wisconsin Breeding Bird Atlas 2 Project.

Table 2.6. Marsh bird species of interest that have been confirmed (“C”) as breeding or are suspected to breed (“Pr” = “probable”; agitated adult, courtship display, copulation) in the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC) listed by priority area / site based on the Wisconsin Breeding Bird Atlas 2 Project (eBird 2017) and local experts (T. Prestby and E. Giese, *pers. comm.*) between 2014 and 2017. Local expert, Tom Prestby, discovered a young Gadwall brood and parent near the Cat Island Chain Restoration Site in 2014, though the exact nest location is not known but suspected to have originated from the Duck Creek area or Peters Marsh. Many relatively young Yellow-headed Blackbirds have been reported at the Cat Island Chain Restoration Site though no nest has yet been found at that site, though they breed at the neighboring Peters Marsh (T. Prestby, *pers. comm.*). Sandhill Crane may also breed (“probable” record) at the Cottage Grove Complex west of Peters Marsh (eBird 2017).

Species / Site	Barkhausen Waterfowl Preserve	Bay Beach West	Cat Island Chain Restoration Site	Dead Horse Bay / Longtail Point	Duck Creek Area	Ken Euers	Peters Marsh	Pt. Sable	UW-Green Bay	WPS / Pulliam Plant
American Bittern							C			
American Coot				C	C	C	C			
Blue-winged Teal			C			C	C			
Common Gallinule				C			C			
Gadwall			C?		?		?			
Least Bittern							C			
Marsh Wren				C	Pr		C	Pr		
Pied-billed Grebe	Pr			Pr	C		C	Pr		
Sandhill Crane	C	C		C	C		C	C	C	
Sedge Wren								Pr		
Sora		Pr		Pr	C		C	Pr		
Swamp Sparrow					C		C	Pr		Pr
Virginia Rail							C			Pr
Wilson’s Phalarope			C							
Wilson's Snipe	Pr						Pr			Pr
Yellow-headed Blackbird			C?	C	C		C			C

Bay Beach Wildlife Sanctuary West/East and Point Sable belong to the Lower Green Bay Islands-Bay Beach Wildlife Sanctuary Important Bird Area (IBA; Important Bird Areas webpage). The Duck Creek Delta and entire west shore belong to the Green Bay West Shore Wetlands IBA, which was identified for its importance of providing marsh bird nesting habitat (Important Bird Areas webpage). Although degraded by invasive species and other impacts, these areas continue to provide some of the most significant wildlife habitat in the LGB&FR AOC.

Marsh breeding birds are important environmental indicators because many of these species are predators of aquatic invertebrates or small vertebrates (anurans, larval fish) that reflect the ecological health of coastal or nearshore biotic communities. As secondary or tertiary consumers, marsh birds are vulnerable to bioaccumulation of environmental contaminants, such as pesticides, heavy metals, and polychlorinated biphenyls (PCBs; Qualls et al. 2013). While the diets of individual marsh breeding birds vary greatly, wrens and warblers, like many songbirds, primarily eat insects and aquatic invertebrates. Blackbirds eat aquatic insects, invertebrates, and seeds (Twedt and Crawford 1995). Common Gallinules and American Coots forage on aquatic invertebrates, aquatic plants, seeds, and fish (Bannor and Kiviat 2002, Brisbin Jr. and Mowbray 2002), while bitterns eat insects, anurans, fish, and other aquatic invertebrates (Lowther et al. 2009, Poole et al. 2009). Blue-winged Teal consume aquatic invertebrates, aquatic plants, seeds, and even algae (Rohwer et al. 2002). Pied-billed Grebe eat fish and aquatic invertebrates/insects

(Muller and Storer 1999), and rails feed on aquatic invertebrates, insects, and aquatic plants/seeds (Conway 1995, Melvin and Gibbs 2012).

Between 1834 and 1975, approximately 364 ha (3.64 km^2) of 407 ha (4.07 km^2) of emergent marsh habitat were lost between the Fox River and Duck Creek due to the construction of Highways 41 and 141, a municipal landfill, and dredge spoil deposition (Bosley 1978). Between Duck Creek and the Little Suamico River, 192 ha (1.92 km^2) of 256 (2.56 km^2) of wetland were also lost (Bosley 1978). Recognizing significant losses in these and other local wetland habitats, the original RAP stated that the LGB&FR AOC needs to improve and maintain “healthy, self-sustaining, naturally reproducing, and diverse populations” of dabbling ducks and other marsh nesting bird (Wisconsin Department of Natural Resources 2016a).

Ongoing surveys of marsh birds by the Great Lakes Coastal Wetland Monitoring Program (CWMP), augmented by point counts conducted during this project, yield a baseline condition of approximately 6.0 for emergent marsh breeding birds in the LGB&FR AOC (Figure 2.25). Despite significant losses of historical wetland habitat (Bosley 1978), many marsh species are still well-established in this ecosystem (Table 2.6). The marshes that remain, however, are dominated by aggressive, invasive plant species, including common reed (*Phragmites australis*) and the hybrid cattail (*Typha × glauca*) in the emergent marshes and Eurasian watermilfoil (*Myriophyllum spicatum*) in the submergent marshes. These invasives need to be controlled and replaced by an appropriate mix of open water native emergent vegetation and submerged aquatic plants. Because wetland habitats may change dramatically during periods of varying water levels, a long-term management plan for sustaining emergent wetland habitat at sensitive wetlands during both high and low water periods is necessary.

Our recommended assessment metric is an Index of Ecological Condition (IEC; e.g., Howe et al. 2007) ranging from 0-10, based on 30 marsh-obligate or marsh user taxa (Figure 2.25). Biotic responses of these taxa (species or species groups) are based on results from the CWMP (Uzarski et al. 2017), including wetlands from across the Great Lakes. To represent the entire LGB&FR AOC, we propose an average value for the 20 best independent wetland survey points, separated by at least 500 m (Figure 2.25).

The condition of marsh breeding birds in the LGB&FR AOC can be improved by enhancing habitat of wet meadow species like Sedge Wren, Sandhill Crane, and American Bittern. Existing southern sedge meadow remnants at the Malchow-Olson Tract, Point au Sable, Fort Howard Wildlife Area, Duck Creek, and small areas upstream along the East River can be expanded, and invasives at these sites must be controlled and replaced with natives. Improvements in the extent and quality of other coastal emergent marshes also will lead to higher IEC values, especially targeting species like Northern Harrier, Swamp Sparrow, Wilson’s Snipe, and waterfowl. The requirement of 20 independent survey locations means that improvements in areas that have previously been given little attention or are currently marginal in quality (e.g., Fox River coastal zone, Duck Creek west, Ken Euers Nature Preserve) may lead to significant improvements in our recommended metric.

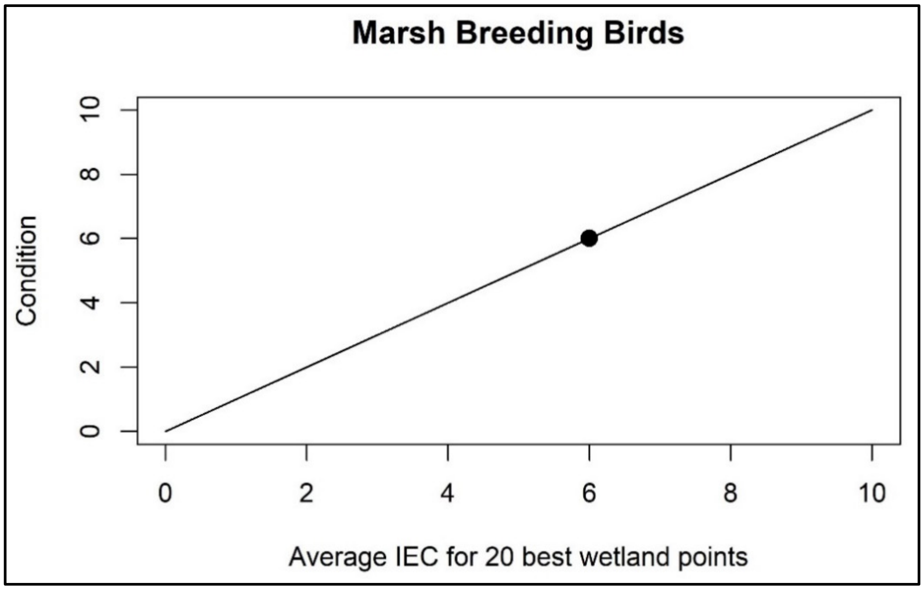


Figure 2.25. Marsh breeding bird assessment for the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC). The x-axis represents the bird metric (scaled from 0 [poor condition] to 10 [ideal condition]), which is determined through field surveys and application of the Index of Ecological Condition (IEC; Howe et al. 2007). The field metric is the average IEC for the 20 best wetland points in the LGB&FR AOC.

Marsh breeding birds: American Coot family (left, taken by Thomas Prestby) and Least Bittern (right; taken by Erin Giese).

Coastal Terrestrial Macroinvertebrates

Coastal meadows and beaches of the LGB&FR AOC provide potential habitat for a wide range of terrestrial or semi-terrestrial invertebrates, some of which are rare or threatened. For example, Jay Watson (*pers. comm.*) observed and photographed the state endangered hairy-necked tiger beetle (*Cicindela hirticollis rhodensis*) at the Cat Island Chain Restoration Site and the federally endangered rusty-patched bumble bee (*Bombus affinis*) at the UW-Green Bay campus during 2016-2017, both within the 1 km coastal zone of the LGB&FR AOC. Populations of other uncommon species, including beach specialists like the seaside grasshopper (*Trimerotropis maritima*) and the state endangered Lake Huron locust (*Trimerotropis huroniana*), could become established if appropriate habitat is restored in the LGB&FR AOC coastal zone. Native pollinators, including declining bumble bees (*Bombus* spp.), monarch butterfly (*Danaus* *plexippus*), Baltimore checkerspot (*Euphydryas phaeton*), and others have been observed by us in openings or meadows along lower Green Bay or Fox River.

The species group "coastal terrestrial macroinvertebrates" includes state and federally listed invertebrates and other uncommon or ecologically sensitive species found on beaches, wet meadows, openings, and other habitats close to the LGB&FR AOC shoreline. Isard et al. (2001) described how aerial-dispersed insects accumulate along shorelines of the Great Lakes, including non-native species and pests. Their findings imply that desirable species may readily recolonize coastal habitats restored with native plant species and nesting substrates. This favorable geographic position of coastal habitats may make them especially important for conservation of native pollinators and other native insects, which have experienced widespread declines during recent decades (Potts et al. 2010, Cameron et al. 2011, Colla et al. 2012, Carvalheiro et al. 2013, Lever et al. 2014, Hallmann et al. 2017).

Two habitats of the aquatic-terrestrial interface, Great Lakes beaches and southern sedge meadows, are particularly imperiled in the LGB&FR AOC. Restoration planning for these and other habitats should address the specific requirements of native invertebrates. Specifically, sandy substrates are used by many insects, spiders, and other arthropods for nests and burrows; native flowering plants are used by butterflies, bees, and other pollinators; and specialist insect herbivores like monarch, Baltimore checkerspot, and other butterflies require specific host plants for larval development. These habitat features should be incorporated into future habitat restoration plans.

Although rare coastal macroinvertebrates have been documented in the LGB&FR AOC, no systematic survey has been conducted and few if any habitat restoration projects have targeted invertebrates anywhere in the LGB&FR AOC. As a result, we have designated the baseline condition for this group as 3 on a scale of 0-10 (Figure 2.26). Assessing the status of such a diverse and little-known group of animals is an enormous challenge, so we propose a simple metric that focuses on habitat restoration rather than on population or community measures. Our ideal condition (10) will be achieved when 10 significant local projects are implemented for the benefit of one or more coastal terrestrial invertebrate species (Figure 2.26). We define "significant local projects" as projects that provide at least 3 ha of protected and managed habitat for one or more uncommon coastal terrestrial invertebrates. An example of a project includes planting native herbaceous host/pollinator plants and maintaining open sand habitat at the Cat Island Chain Restoration Site. Another would be to plant turtlehead (*Chelone glabra*), milkweeds (*Asclepias* spp.) and perhaps other native insect host plants in southern sedge meadow or shrub carr restoration projects, benefitting native pollinators like the Baltimore checkerspot, monarch, and other host plant specialists. Another project would be to maintain large areas of open sandy substrates for the benefit of nesting native bees and Great Lakes sand specialists like *Trimerotropis* grasshoppers and the hairy-necked tiger beetle. Each project added to the current coastal environment would elevate the condition of this species group by 1 point (on a 0-10 scale). Ideally, land managers eventually would establish at least 10 special coastal macroinvertebrate conservation sites within the LGB&FR AOC.

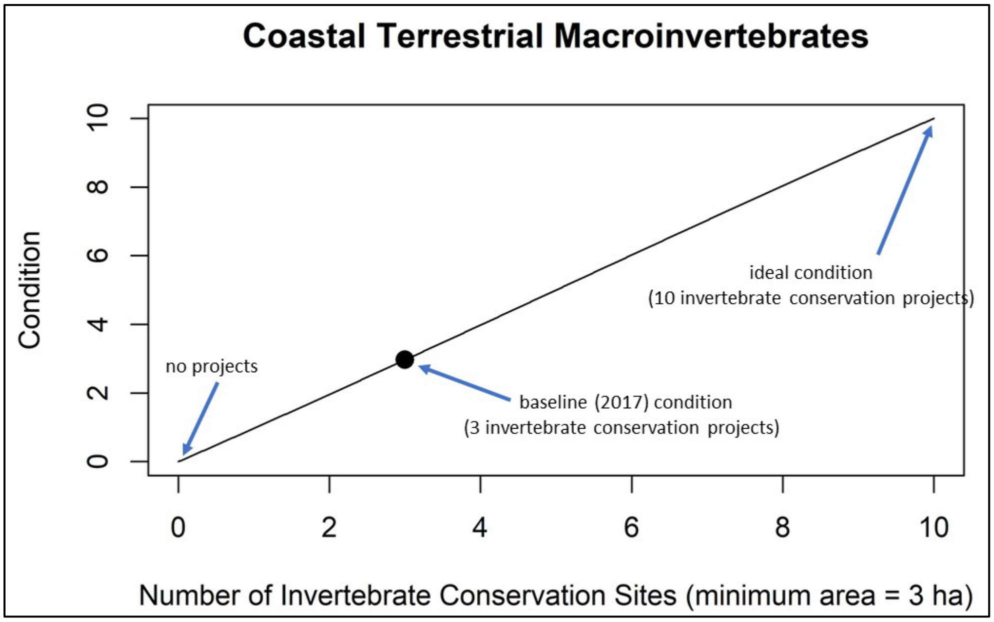


Figure 2.26. Coastal terrestrial macroinvertebrates assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the number of invertebrate conservation sites that are a minimum of 3 ha in size (scaled from 0 [no projects] to 10 [ideal condition or 10 projects]), which is determined through field surveys. The y-axis is the converted condition for a given IEC score, which ranges from poor condition (0) to good/ideal condition (10).

Coastal terrestrial macroinvertebrates: sand grasshopper (left, taken by Robert Howe) and hairy-necked tiger beetle (right; *Cicindela hirticollis rhodensis*, taken by Jay Watson).

Shorebirds (migratory)

The “shorebirds (migratory)” species group consists of approximately 25 shorebirds (Order Charadriiformes) that regularly use shoreline, coastal, and wetland habitats in the LGB&FR AOC as stopover habitat during spring or fall migration. This group includes plovers, sandpipers, godwits, dowitchers, yellowlegs, phalaropes, and other subgroups, but not terns, gulls, breeding Piping Plover (*Charadrius melodus*), and other waterbirds that are represented in other priority species groups. We also exclude locally breeding shorebirds, such as Killdeer (*Charadrius vociferus*), Spotted Sandpiper (*Actitis macularius*), and Wilson’s Snipe (*Gallinago delicata*), to avoid inflated migrant numbers during assessment surveys. Major stopover habitats for migratory shorebirds are mud flats, Great Lakes beach, rocky shorelines, open wetlands, shallow waters along the coastline, grasslands, and even flooded agricultural lands in the coastal zone (Helmers 1992, de Szalay et al. 2000). Peak migratory concentrations in lower Green Bay usually occur from late May through early June (spring migration) and August through September (fall migration), although fall migrants (usually post-breeding adults) begin to appear as early as mid-July, and some shorebirds persist well into October (Prestby 2015). Most migratory North American shorebirds breed in arctic or sub-arctic regions of northern Canada and Alaska and winter along the coast or wetlands of Central America, the southern United States, or Mexico.

Great Lakes coastal areas provide critical stopover habitat for shorebirds traveling through the interior of North America after long, often non-stop flights from wintering or breeding grounds (Diehl et al. 2003). The lower Green Bay coastal zone provides protein-rich food sources, such as aquatic insects, worms, snails, midges, and other invertebrates (Helmers 1992). Depending on shorebird species, body shape, and bill size, different species forage for food using different techniques. Plovers, for example, are terrestrial/aquatic gleaners, which means that they glean or pick up food along the habitat they are using (Helmers 1992). Aquatic probers, like godwits, use their bills to probe food from mud or sand substrates (Helmers 1992). Migratory shorebirds are important because they are predators of aquatic species that depend on the coastal or nearshore environment, which may contain environmental contaminants such as pesticides, heavy metals, and polychlorinated biphenyls (PCBs; Qualls et al. 2013, Russell et al. 2016).

The importance of lower Green Bay as a stopover site for shorebirds was recognized by Potter et al. (2007), but more recently Prestby (2015) has documented an extraordinary and diverse migration of shorebirds at the Cat Island Chain Restoration Site, which was constructed to restore the historical Cat Island Chain of barrier islands (Figure 2.27). The Cat Island Chain Restoration Site is located within the Green Bay West Shore Wetlands Important Bird Area (Important Bird Areas webpage) near Peters Marsh on the west shore of Green Bay. Public access to this site is prohibited for the protection of wildlife and because it is an active construction site. While migratory shorebirds use other stretches of undeveloped Great Lakes beach, wetlands, and natural habitats in the LGB&FR AOC, we identify just two important migratory shorebird hotspots: the Cat Island Chain Restoration Site and Point au Sable (T. Prestby, *pers. comm.*; Figure 2.27), which includes more than 2 km of undeveloped beach habitat. Historically, three large barrier islands comprised the Cat Island Chain, providing critical fish and wildlife habitat off the west shore of the lower bay. However, due to unusually high water levels, massive storms, and hardened shorelines, nearly all of these islands washed away during a storm event during the spring of 1973. In the 1988 RAP, a group of local conservationists proposed the idea of reconstructing these islands (Wisconsin Department of Natural Resources 2016a). The idea materialized >20 years later. By May 2013, the Cat Island Chain Restoration Site and framework of three island “cells” were constructed. Two of the “cells” have been filled with some dredge material from the Port of Green Bay shipping channel. Over the next 20-30 years, additional dredge material will be added to each of the three “cells.” So far, the dredge material deposited in the westernmost “cell” has largely consisted of sand, silt, and clay, which has in turn created excellent shorebird habitat. Thomas Prestby’s (2015) master thesis provided a baseline study of migratory shorebirds in the lower bay, perfectly timed to coincide with the construction of the Cat Island Chain Restoration Site. He documented >30 species of shorebirds at the Cat Island Chain Restoration Site between 2013 and 2014. In fact, Prestby’s (2015) study showed that the Cat Island Chain Restoration Site is the most important and diverse migratory shorebird stopover location in the entire state of Wisconsin (eBird 2017). Migrant shorebirds that use the barrier relatively frequently include Black-bellied Plover (*Pluvialis squatarola*), Semipalmated Plover (*Charadrius semipalmatus*), Ruddy Turnstone (Arenaria *interpres*), Sanderling (*Calidris alba*), Baird’s Sandpiper (*Calidris bairdii*), Least Sandpiper (*Calidris minutilla*), Pectoral Sandpiper

(*Calidris melanotos*), Semipalmated Sandpiper (*Calidris pusilla*), Greater Yellowlegs (*Tringa melanoleuca*), and Lesser Yellowlegs (*Tringa flavipes*; eBird 2017, Prestby 2015).

Especially during lower water years, Point au Sable provides important migratory shorebird stopover habitat along the east shore of the bay. Foraging habitat for shorebirds occurs on the outer perimeter of the peninsula (Great Lakes beach) and in wet, muddy areas along the edges of the inner lagoon (Figure 2.27). Point Sable is located within the designated Lower Green Bay Islands-Bay Beach Wildlife Sanctuary Important Bird Area (Important Bird Areas webpage). At Point Sable, Prestby (2015) reported Greater Yellowlegs, Lesser Yellowlegs, Ruddy Turnstone, Dunlin, Least Sandpiper, and several other species.

Figure 2.27. Two migratory shorebird hotspots within the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC) based on Prestby (2015), eBird records (2017), and our expert opinion. The Cat Island Chain Restoration Site is not only the best and most diverse migratory shorebird stopover site in the LGB&FR AOC but also across the state of Wisconsin. There is no public access to the Cat Island Chain Restoration Site, however, at this time. Map was made using Google Earth Pro software.

Changing water levels in the bay can greatly impact the number and types of shorebirds that migrate through the LGB&FR AOC. Stopover locations with mud and exposed shoreline that are available to shorebirds on one day may become flooded days or weeks later if water levels rise along the coastal zone (Ewert et al. 2005, Potter et al. 2007, Prestby 2015). The same is true of temporarily flooded agricultural fields, which often dry quickly due to drain tiles or soil infiltration. Controlling water levels in diked wetlands or strategically timing the deposition of dredge material in the “cells” of the Cat Island Chain Restoration Site, for example, can help provide reliable stopover habitat for migrant shorebirds (Ewert et al. 2005, Prestby 2015). Maintaining gradually sloped mudflats in the recently placed dredge material in the Cat Island Chain Restoration Site “cells” will maximize the amount of stopover habitat for shorebirds across different water levels (Prestby 2015).

The RAP originally noted that the LGB&FR AOC needs “unconsolidated beaches (for shorebirds)” including state or federally-listed species (Wisconsin Department of Natural Resources 2016a). Listed shorebird species found in the LGB&FR AOC include the federally and state endangered Piping Plover (though this species is excluded from the migratory shorebirds group), federally threatened Red Knot (*Calidris canutus*), and seven species of state special concern species: American Golden-Plover (*Pluvialis dominica*), Buff-breasted Sandpiper (*Tryngites subruficollis*), Dunlin (*Calidris alpina*), Hudsonian Godwit (*Limosa haemastica*), Short-billed Dowitcher (*Limnodromus griseus*), Solitary Sandpiper (*Tringa solitaria*), and Wilson’s Phalarope (*Phalaropus tricolor*). Current threats to migratory shorebirds include habitat loss and degradation, residential development (particularly on shorelines), invasive species, and climate change (Russell et al. 2016).

Based on eBird (2017) records and our expert opinion, we assign a baseline condition of 5.0 to this group. Currently the lower bay shorebird assemblages are quite diverse and abundant, though the group is largely dependent on just two primary migratory stopover sites (Figure 2.27). One of the most important future actions will be to develop and implement a Cat Island Habitat and Wildlife Management Plan that addresses invasive plant species control, colonization by abundant cottonwood (*Populus deltoides*) seedlings, strategic placement of dredge material, public access restrictions, and shoreline management. Management for intermittently flooded shoreline habitat on the Cat Island Chain Restoration Site is needed. Invasive species control along Point Sable’s beaches, which are vulnerable to *Phragmites* and dreissenid mussel shells, likewise will improve the condition of migratory shorebirds in the LGB&FR AOC. Shallow, low-gradient shorelines of other wetlands and ponds within the coastal zone may additionally improve the status of migratory shorebirds in the LGB&FR AOC.

Like migratory landbirds, objectively assessing the condition of migratory shorebirds in the LGB&FR AOC is challenging because numbers of shorebirds are dependent on events elsewhere, including breeding and wintering areas hundreds or in some cases thousands of kilometers from Green Bay. Nevertheless, shorebird migration is an important, if transient, feature of the LGB&FR AOC wildlife. Prestby (2015) used a 20-minute, unlimited-distance point count to quantify shorebirds at 19 locations in lower Green bay, including 11 within the LGB&FR AOC boundaries. Five of these points were located at the Cat Island Chain Restoration Site and four were located at Point Sable. Other important shorebird sites in the LGB&FR AOC could be restored or enhanced (e.g., Duck Creek/Ken Euers Nature Area; UW-Green Bay Shore Woods and Beach; Longtail Point). Certainly, at least six quality migratory shorebird stopover sites are both desirable and achievable within the LGB&FR AOC. We propose an assessment metric defined as the average quality (on a scale of 0-10) of the six highest quality shorebird stopover points in the LGB&FR AOC (Figure 2.28). Points must be at least 500 m apart, meaning that up to four points potentially could be located at the Cat Island Chain Restoration Site. If only five sites are present, the sum of the five quality metrics still would be divided by six, ensuring that a score of 10 can be obtained only when six points reach maximal quality (Figure 2.28). Quality can be defined by the number of shorebirds (of any species except locally breeding Killdeer, Spotted Sandpiper, and Wilson’s Snipe) present during peak migration, dates of which will vary from year to year. The best points at the Cat Island Chain Restoration Site have yielded 400 or more individual migrant shorebirds on exceptional days but a more typical number during peak migration is between 50 and 200 individuals (Prestby 2015). The conversion curve for determining quality (0-10) at an individual point based on 20-minute point counts is nonlinear (Figure 2.28), reflecting this threshold range from 50-200 shorebirds. Note that any six points can be used to calculate the average, and the location of these points might differ from year to year.

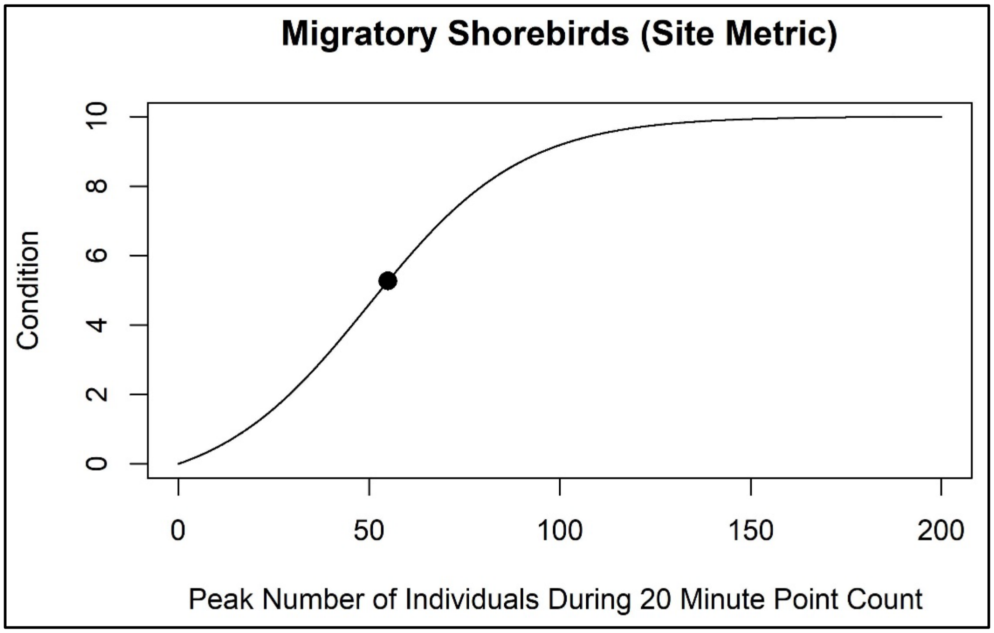


Figure 2.28. Migratory shorebirds' conversion curve to estimate the condition of a single site based on 20-minute point count(s) during peak spring or fall migration. Multiple counts may be conducted at the site; the maximum number of individuals (x-axis) is used for this conversion, yielding a condition between 0-10 (y-axis). Overall condition of migratory shorebirds is calculated as the average condition among the six best sites within the LGB&FR AOC.

Left to right: Least Sandpiper, Greater Yellowlegs, Lesser Yellowlegs, and Ruddy Turnstone. Photographs taken by Scott Giese.

Waterfowl (migratory)

Migratory ducks, geese, and swans comprise one of the most visible and economically important species groups in the LGB&FR AOC. Prince et al. (1992) recognized Green Bay as one of 15 concentration areas for migratory waterfowl in the Great Lakes and by far the most heavily used site in Lake Michigan for diving ducks and sea ducks. Harris (1998) found that numbers of diving ducks increased after invasion of non-native dreissenid mussels between 1977-78 and 1994-97. This result is consistent with studies by Mazak et al. (1997), Badzinski and Petrie (2006), and Schummer et al. (2010), who showed that dreissenids are major components in the diets of scaup (*Aythya* spp.) and other divers in the Great Lakes.

The northeast-southwest orientation of Green Bay creates a natural landmark for migrants, and the shallow, lower bay supports productive waterfowl food resources, even though it has been highly modified by pollution and invasive species. Submerged aquatic vegetation, abundant aquatic macroinvertebrates (particularly dreissenid mussels), and a rich and productive fish community attract tens of thousands of diving ducks in the lower bay, creating a "destination" for birdwatchers and hunters.

During 2016-17 we enlisted Thomas Prestby to conduct a shore-based survey of waterfowl from eight strategic locations in in the LGB&FR AOC and two localities (Sensiba Wildlife Area and Bay Shore County Park) just north of the LGB&FR AOC (See Figure 1 in Appendix 1.3; Figure 2.32). During 263 counts on 30 survey days, he recorded 28 species of waterfowl (15 diving ducks, 9 marsh ducks, 2 geese, and 2 swans). Waterfowl rafts were counted and mapped during each survey (example, Figure 2.30) as well as in relation to accompanying water depths (Figure 2.40 and Table 2.12).

Fall migration begins in Great Lakes coastal marshes during late August, when Blue-winged Teal (*Anas discors*) assemble in migratory flocks (Soulliere et al. 2007) prior to their departure in late September. Our surveys did not begin until October 12th, but numbers of Blue-winged Teal in the lower bay were not high during the corresponding spring migration period in 2017. Other marsh ducks including Wood Duck (*Aix sponsa*), Northern Pintail (*Anas acuta*), Gadwall (*Anas strepera*), Northern Shoveler (*Anas clypeata*), American Wigeon (*Anas americana*), Mallard (*Anas platyrhynchos*), American Black Duck (*Anas rubripes*), and Green-winged Teal (*Anas crecca*) occur in modest numbers during October, but the lower bay does not appear to be a major stopover site for these species. By far the highest numbers were recorded for Mallards, which were abundant winter residents in open water areas at the mouth of the Fox River and below the De Pere Dam. The high count for a single day during winter was 5,491 Mallards on 10 December 2016. Aside from Mallards, the most commonly observed marsh ducks in the LGB&FR AOC during migration were (in decreasing order of abundance) Gadwall, American Wigeon, Northern Pintail, Green-winged Teal, Northern Shoveler, and American Black Duck.

Canada Geese (*Branta canadensis*) were always present in the lower bay, reaching daily peak numbers of over 500 individuals during early November and continuing at high numbers through the winter (Table 2.9). By mid-April, fewer than 100 Canada Geese were recorded on individual days, presumably because pairs had either departed the area or had dispersed to local breeding sites. Tundra Swans (*Cygnus columbianus*) were observed in the lower bay during late Marsh and early April 2017, with the largest recorded flock of 151 individuals on 22 March 2017. Other noteworthy migratory waterbirds included American Coot (*Fulica americana*; flocks of 500-600+ observed along the Cat Island Chain Restoration Site and Longtail Point during November 2016), two regularly seen species of grebes (Pied-billed [*Podilymbus podiceps*] and Horned Grebe [*Podiceps auritus*]), Common Loon (*Gavia immer*; especially along east shore), Red-throated Loon (*Gavia stellata*), and several rare species recorded on just one or two dates (Trumpeter Swan [*Cygnus buccinator*], Pacific Loon [*Gavia pacifica*], Red-necked Grebe [*Podiceps grisegena*], Eared Grebe [*Podiceps nigricollis*]).

By far the greatest numbers of waterfowl were diving ducks (Table 2.8), especially Greater (*Aythya marila*) and Lesser Scaup (*Aythya affinis*), Common Goldeneye (*Bucephala clangula*), Common Merganser (*Mergus merganser*), and Red-breasted Merganser (*Mergus serrator*). The maximum number of diving ducks (including mergansers) recorded during a single day was 58,448 individuals on 5 March 2017, but Prestby typically estimated more than 10,000 divers on days during late November and early December 2016 and from early March through late April

2017. Even less abundant species like Ruddy Duck (*Oxyura jamaicensis*; maximum 3,236 individuals on 15 April 2017), Redhead (*Aythya americana*; 3,980 individuals on 3 April 2017; Figure 2.39), Canvasback (*Aythya valisineria*; 2,550 individuals on 3 April 2017), Long-tailed Duck (*Clangula hyemalis*; 793 individuals on 10 May 2017), Ring-necked Duck (*Aythya collaris*; 406 individuals on 9 April 2017), and Bufflehead (*Bucephala albeola*; 203 individuals on 11 November 2016) were well represented.

As long as open water was present, diving ducks (and Mallards) were present in large numbers during 2016-2017 (Tables 2.7 and 2.8). During winter all ducks were concentrated below the De Pere Dam or in open water at the mouth of the Fox River (Figure 2.38). By late February some open water appeared off the Cat Island Chain Restoration Site in the Green Bay shipping channel, and by late March open water was widespread. Once open water was present throughout the lower bay, the largest numbers of diving ducks were recorded from the east shore (Table 2.10 and Figure 2.38). This pattern was true during both fall and spring. Large numbers of divers also were recorded on the west shore during this time, however (e.g., Redhead, Figure 2.39). The importance of the De Pere Dam and the mouth of the Fox River diminished significantly in late spring and fall (before ice), perhaps due in part to heavy traffic by recreational fishing boats. Marsh (dabbling) ducks were more common on the west shore during spring (Table 2.11). Diving duck rafts also tended to occur in deeper water during fall than in spring (Table 2.12 and Figure 2.40).

We assigned a weighting of 12 for migratory waterfowl (maximum = 16), placing this group in the lower-middle quartile of species/species groups. The difference between high ranked vs. lower middle ranked species/species groups is modest, however, so improvement in the condition of this group will contribute significant progress toward the BUI removal target. Despite high economic importance and clear dependence on the Green Bay aquatic ecosystem, waterfowl were weighted lower because they are present for only part of the year and because demographics outside the LGB&FR AOC strongly influence population numbers.

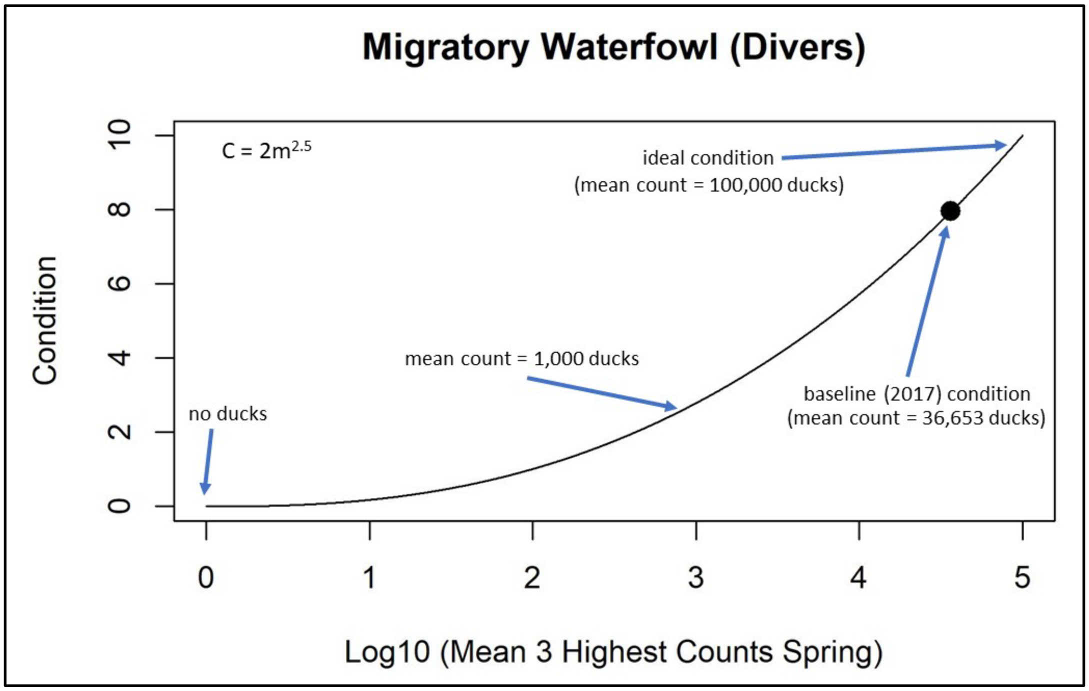
Our estimate of current condition for waterfowl is 6.0, reflecting the high numbers and diversity of species recorded during 2016-2017. We compared our findings with results from Harris (1998). Even though her aerial surveys covered a larger geographic area, numbers of ducks counted from shore during our investigation are comparable, even higher during spring (Figures 2.31-2.37). Diversity of species observed during 2016-2017 also was similar to that observed by Harris (1998), and the distribution of individuals among the dominant species appears to have changed little, if at all.

Shoreline surveys from the eight LGB&FR AOC points sampled by Prestby in 2016-2017 provide a basis for our recommended assessment metric. Spatial distributions of migratory waterfowl during fall are likely influenced strongly by hunters, so we suggest using $\log_{10}$ transformed average counts from the three highest duck totals recorded during spring (1 March-30 April). In order to improve independence of samples and to account for sustained duck numbers, the three highest counts should be separated by at least 1 week (Figure 2.42). The metric should reflect some combination of diving duck numbers (which currently are abundant) and marsh duck numbers (which are less abundant). In this case, the recommended metric is simply the average of two values, $\log_{10}$ average of 3 highest counts of diving ducks and $\log_{10}$ average of 3 highest counts of marsh ducks (Figure 2.42). Future analysis and consultation with experts will be needed to vet and improve this metric. For example, we might wish to use separate biotic response curves (i.e., modeled species' sensitivity to an environmental/disturbance gradient) for different species of diving ducks (e.g., Canvasback, Redhead, scaup, Common

Goldeneye, etc.) and calculate a multispecies IEC rather than lumping all divers together into a single number.

The condition index for migratory waterfowl in the LGB&FR AOC can be most effectively increased by improving conditions for marsh ducks, since their current condition (4.0) is judged to be lower than that of diving ducks (8.0; Figure 2.29). (Badzinski and Petrie [2006], however, note the Lesser Scaup have declined since the mid-1980s in North America, so our optimistic condition for diving ducks needs to be critically examined.) Marsh/dabbling ducks during migration generally consume more plant material than divers (e.g., Knapton and Pauls 1994, Soulliere et al. 2007), although Canvasbacks and Redheads (and to a lesser extent other species of divers) also feed extensively on aquatic vegetation. Migratory duck distributions in lower Green Bay do not appear to exhibit close association with SAV beds (e.g., *Vallisneria americana* and Canvasback in Figure 2.41), but our results are limited and more detailed observations are needed to determine how important SAV is to migrant waterfowl in the LGB&FR AOC. Extensive areas of SAV are present at the west shore of Green Bay and Point au Sable, and opportunities to increase the available SAV exist around the Cat Island Chain Restoration Site. Construction of barriers or aquatic features that reduce local turbulence and increase water clarity may have a positive effect on SAV growth in the lower bay and along the Fox River, particularly near tributary mouths and near the De Pere Dam.

Increasing diversity and abundance of native aquatic plants in emergent coastal wetlands also will improve conditions for migratory waterfowl in the lower bay. Marsh ducks and divers like Bufflehead consume seeds of aquatic plants during migration, so efforts to control invasive *Phragmites australis* and hybrid cattail (*Typha* × *glauca*) likely will be important in increasing habitat quality for migrant waterfowl in the LGB&FR AOC.



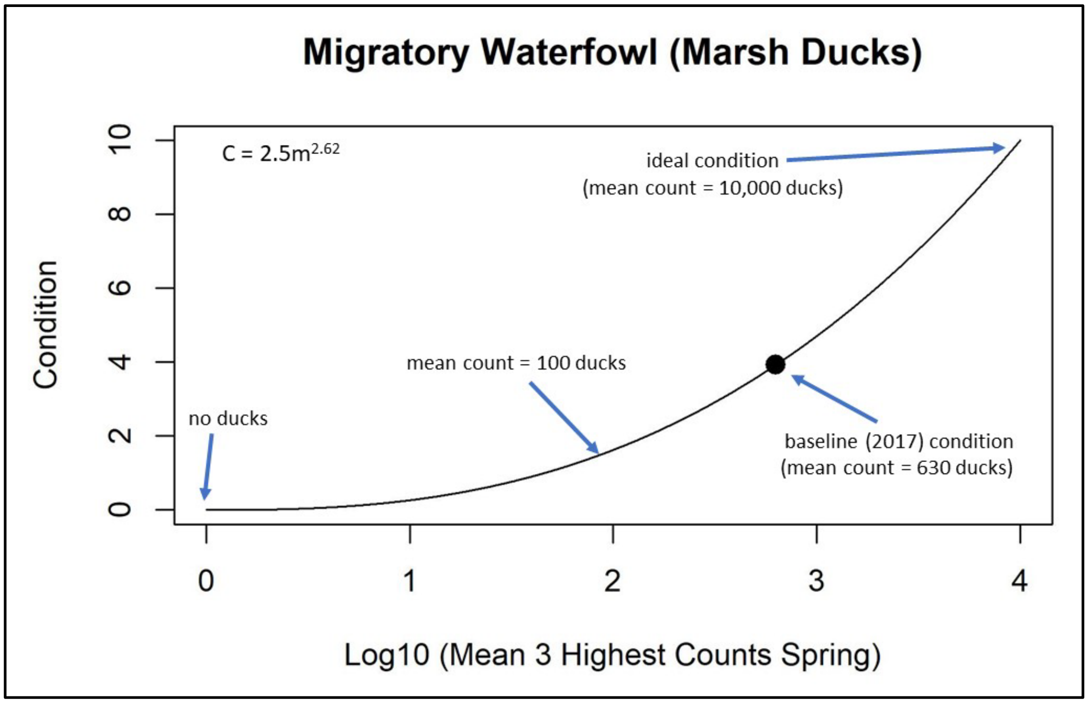


Figure 2.29. Migratory waterfowl assessment of diving ducks (top) and marsh ducks (bottom) for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the average counts from the three highest duck totals recorded during spring (scaled from 0 [no ducks] to 10 [10,000 ducks]), which is determined through field surveys, and the y-axis is the converted condition for a given migratory waterfowl metric score, which ranges from poor condition (0) to good/ideal condition (10).

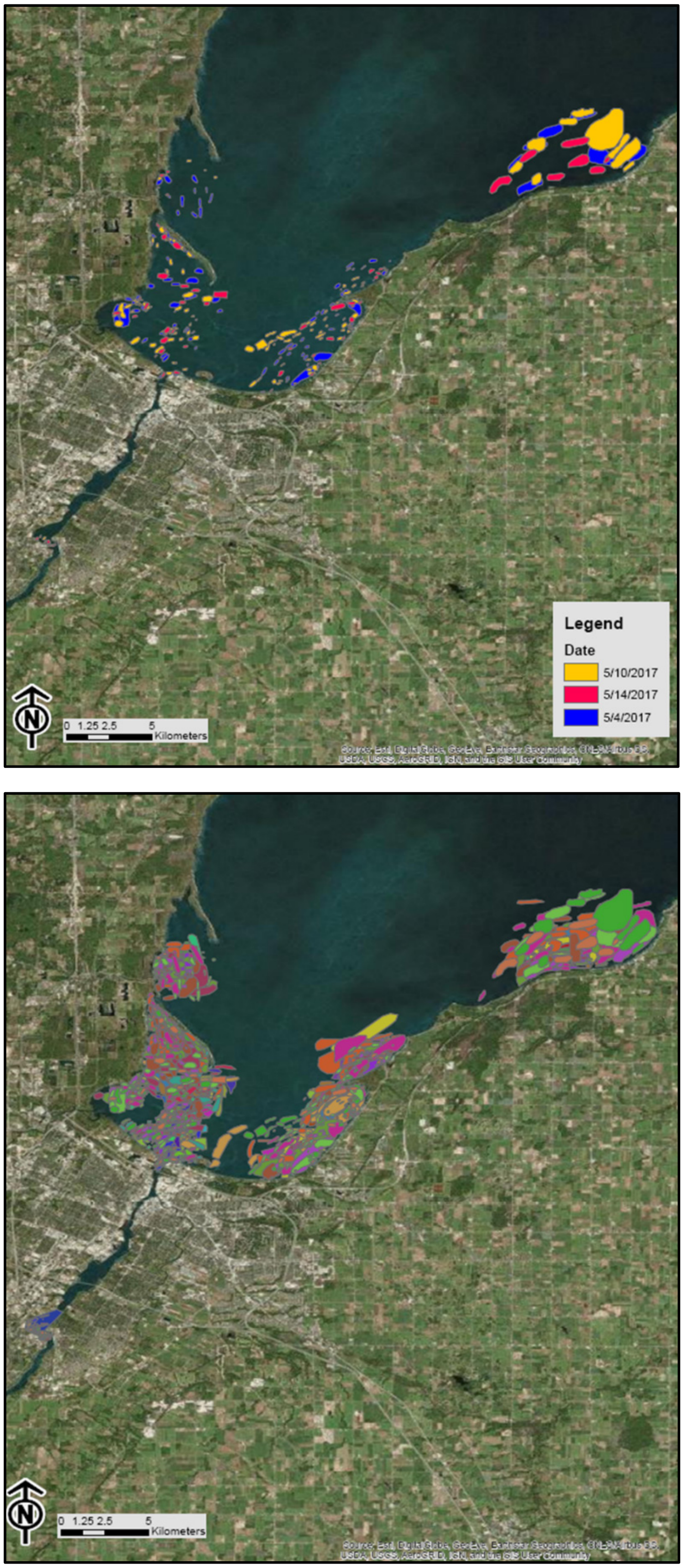


Figure 2.30. Top: Sample map of waterfowl rafts in the Lower Green Bay and Fox River Area of Concern during three of the survey days. Bottom: Map of all waterfowl rafts in the Lower Green Bay and Fox River Area of Concern based on 2016/2017 data.

Historical Comparisons:

Despite smaller survey area, 2016-2017 counts are comparable to previous numbers reported by Harris (1998; Figures 2.31-2.37). In fact, our counts were the highest during spring, when compared to the other data sets. Fall numbers were similar to those from the 1970 but lower than the average from the 1990s (but not significantly).

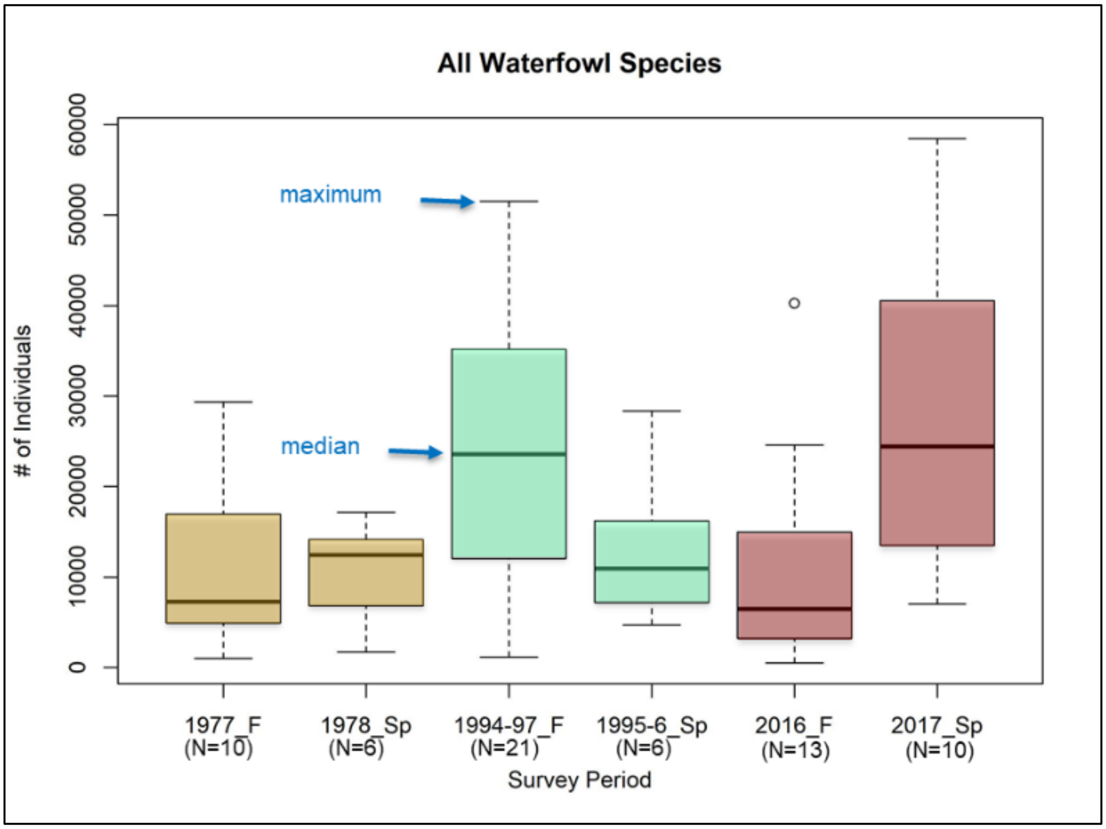


Figure 2.31. Number of individuals of all waterfowl species recorded in fall (F) of 1977, 1994-97, and 2016 and spring (Sp) of 1978, 1995-6, and 2017 based on Harris (1998) and LGB&FR AOC waterfowl surveys that we organized in 2016-17.

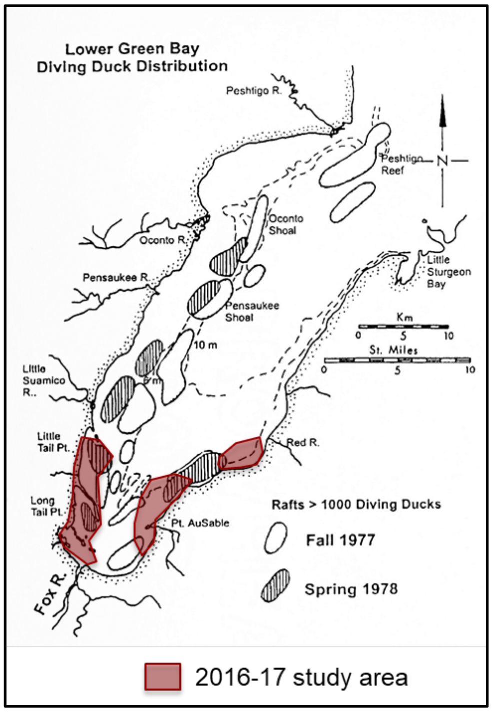


Figure 2.32. Waterfowl survey extent and raft location from Harris (1998) and our 2016-2017 study area.

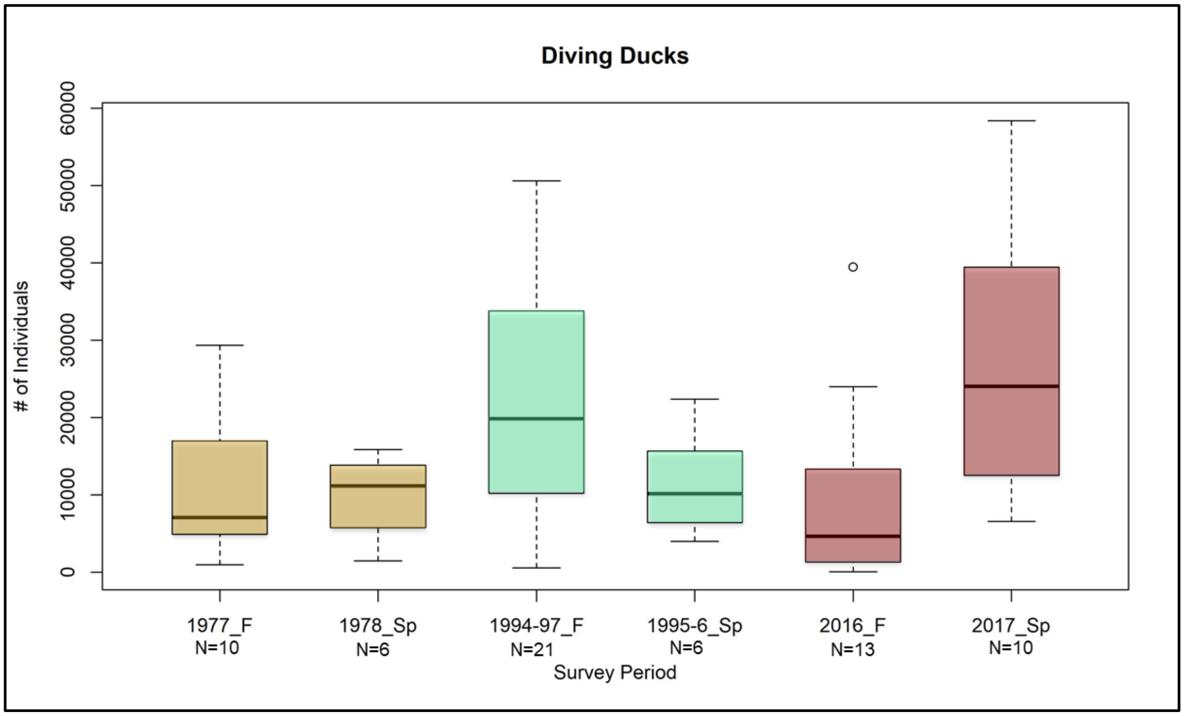


Figure 2.33. Number of individuals of diving ducks recorded in fall (F) of 1977, 1994-97, and 2016 and spring (Sp) of 1978, 1995-6, and 2017 based on Harris (1998) and LGB&FR AOC waterfowl surveys that we organized in 2016-17.

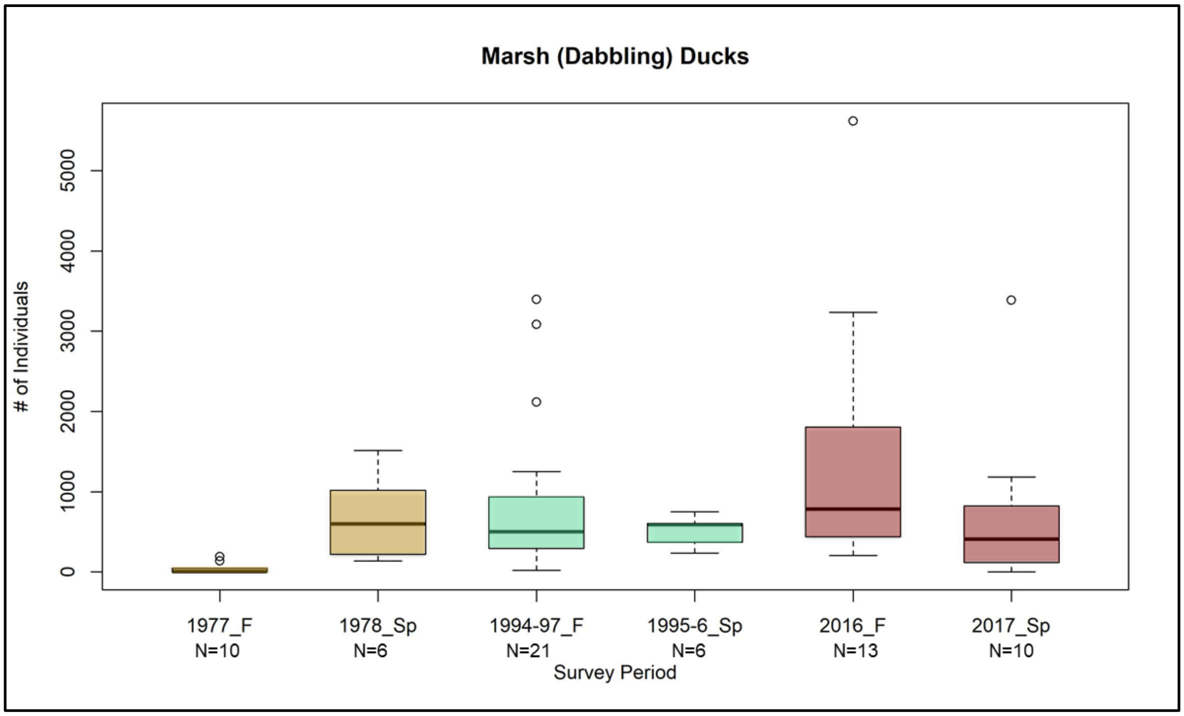


Figure 2.34. Number of individuals of dabbling ducks recorded in fall (F) of 1977, 1994-97, and 2016 and spring (Sp) of 1978, 1995-6, and 2017 based on Harris (1998) and LGB&FR AOC waterfowl surveys that we organized in 2016-17.

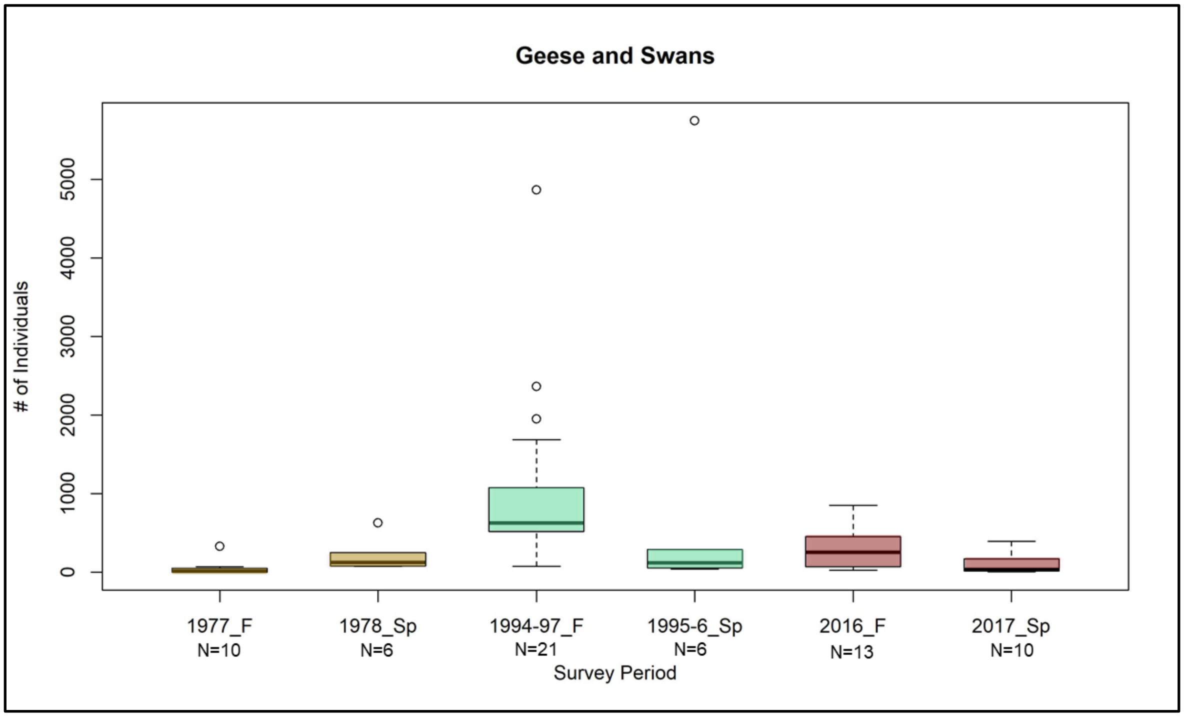


Figure 2.35. Number of individuals of geese and swans recorded in fall (F) of 1977, 1994-97, and 2016 and spring (Sp) of 1978, 1995-6, and 2017 based on Harris (1998) and LGB&FR AOC waterfowl surveys that we organized in 2016-17.

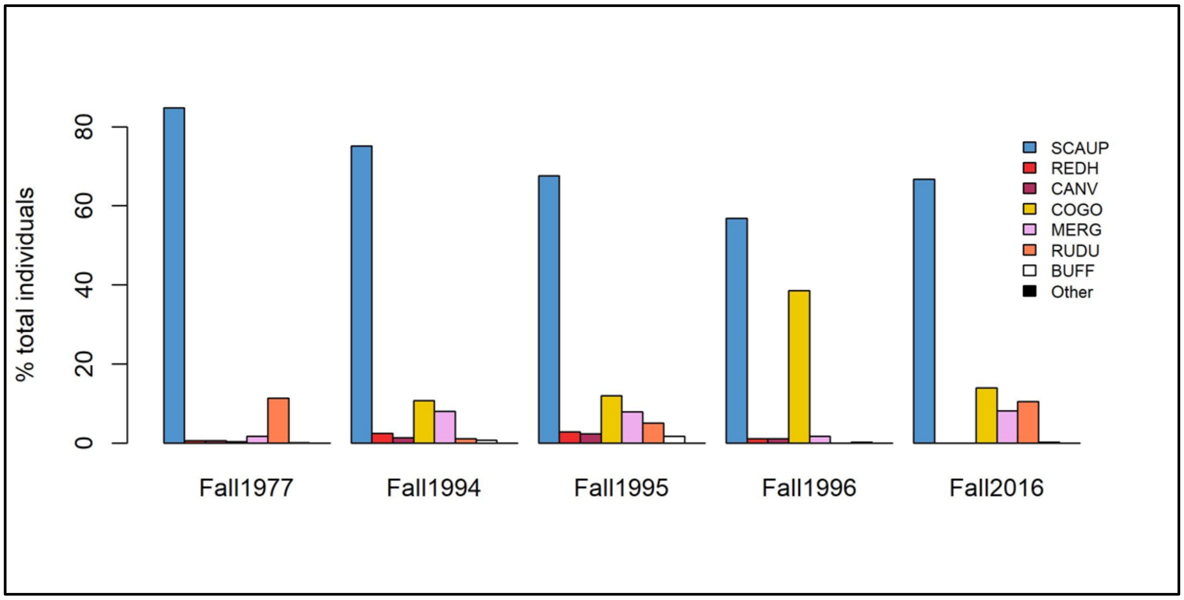


Figure 2.36. Fall diving duck species composition between 1977 and 1994-1996 data from Harris (1998) and our 2016 data.

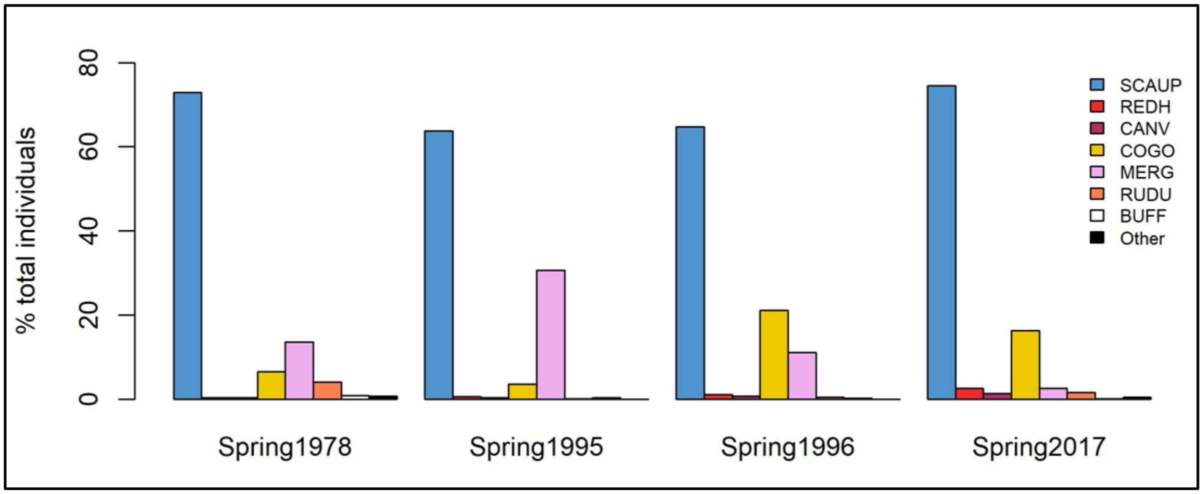


Figure 2.37. Spring diving duck species composition between 1978 and 1995-1996 data from Harris (1998) and our 2017 data.

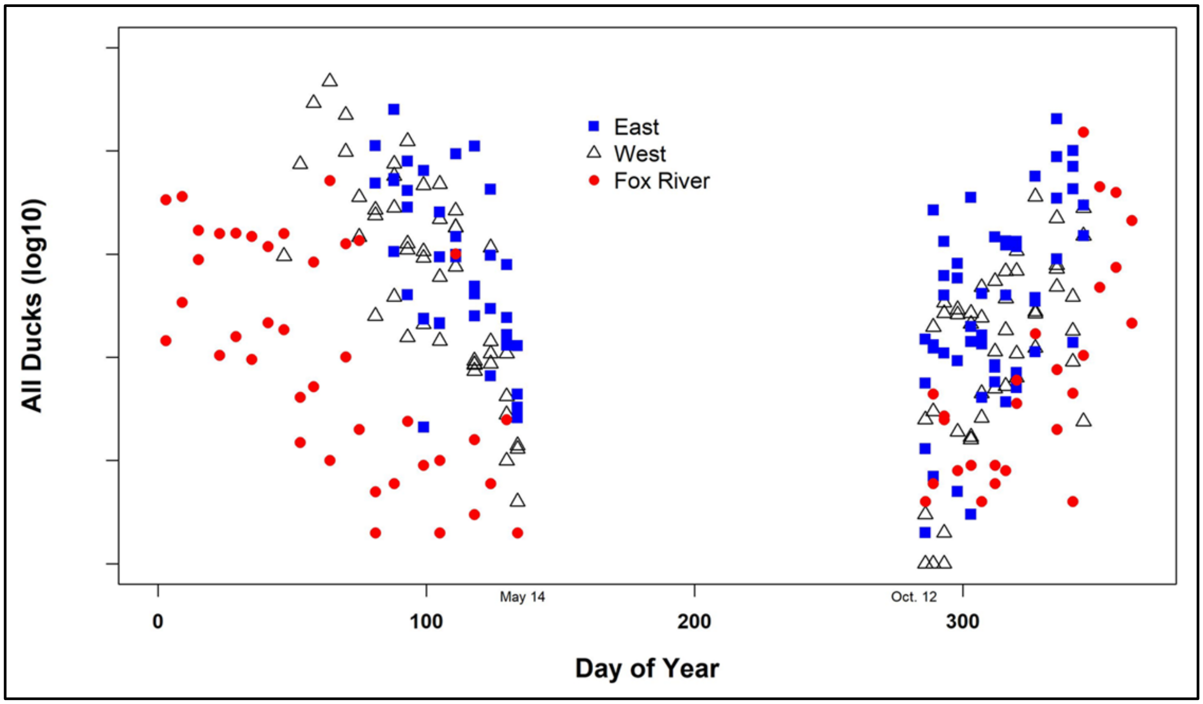


Figure 2.38. Seasonal and spatial variation of all waterfowl across the east and west shores of the Lower Green Bay and Fox River Area of Concern and along the Fox River across days of the year. Winter distributions are influenced by ice conditions.

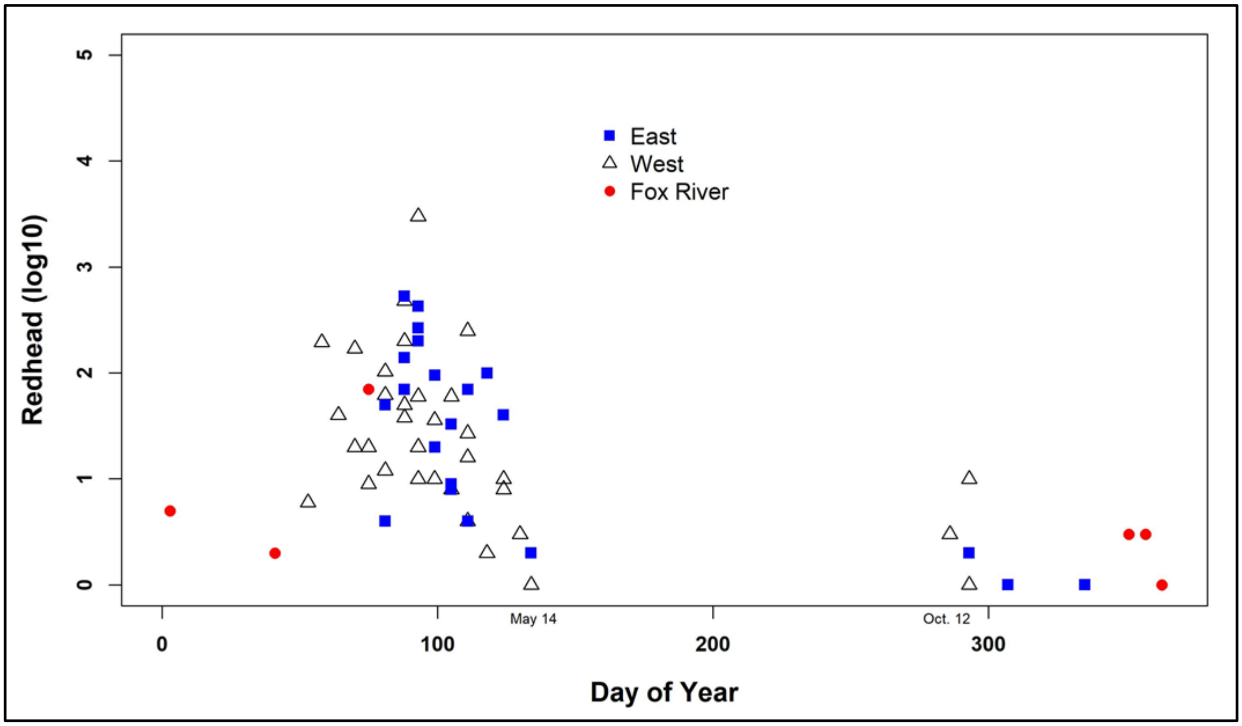
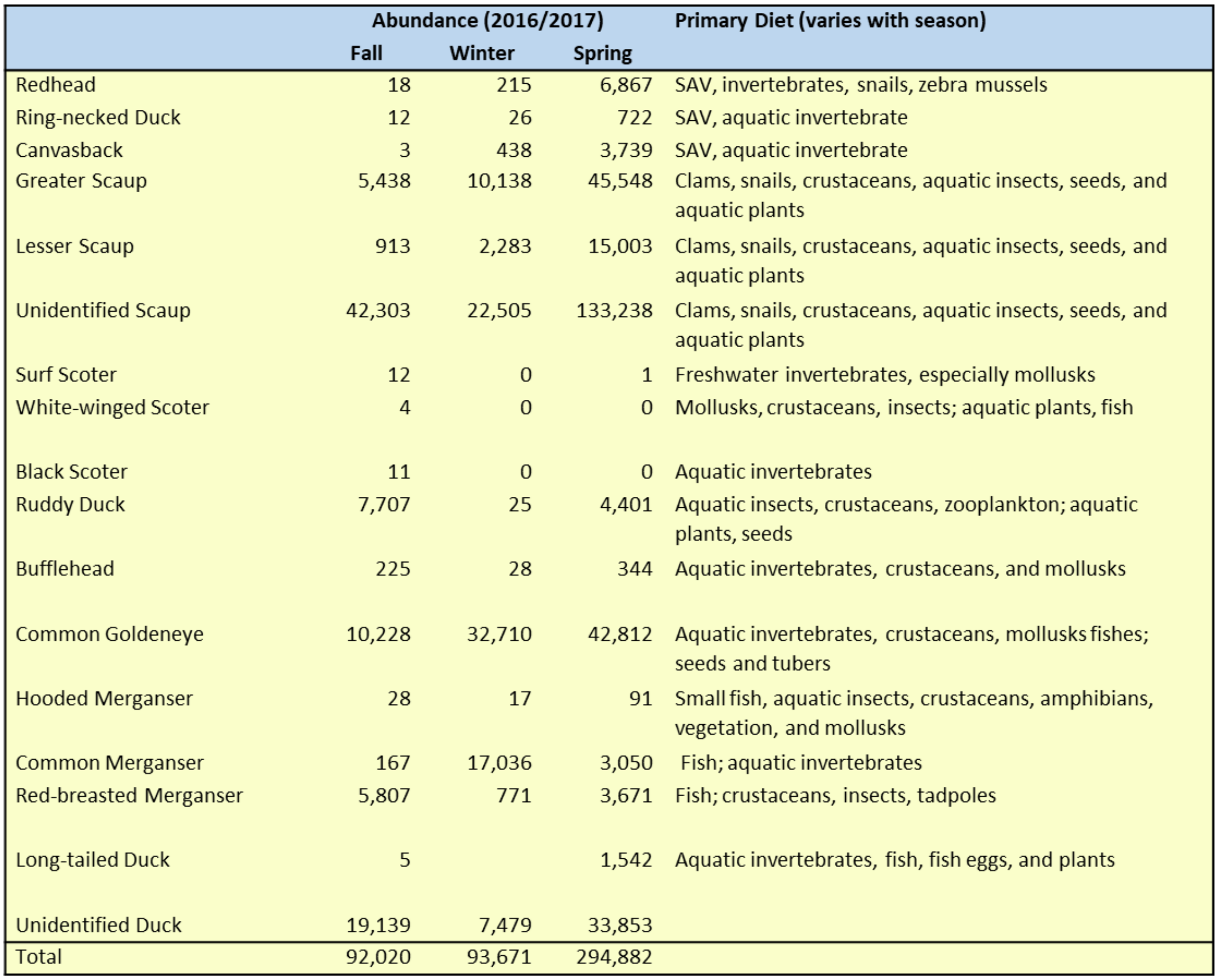


Figure 2.39. Seasonal and spatial variation of Redhead across the east and west shores of the Lower Green Bay and Fox River Area of Concern and along the Fox River across days of the year. Winter distributions are influenced by ice conditions.

Table 2.7. Migratory dabbling (marsh) duck species and abundance during fall, winter, and spring (2016/2017) observed in the Lower Green Bay and Fox River Area of Concern. Diet data gleaned from the Cornell Lab of Ornithology webpage (www.allaboutbirds.org).

Marsh Ducks	Abundance (2016/2017)			Primary Diet
	Fall	Winter	Spring	
Wood Duck	0	0	2	Plants, insects
Gadwall	4	2	608	SAV, insects
Northern Pintail	31	1	194	Grain, seeds; insects, crustaceans
American Wigeon	1	0	277	Aquatic plants; insects, mollusks
American Black Duck	11	230	34	Plants, insects
Mallard	593	14,452	1,182	Seeds, aquatic vegetation; insects
Blue-winged Teal	5	0	17	Vegetation, grains; Invertebrates
Green-winged Teal	109	0	119	Seeds, invertebrates
Northern Shoveler	22	4	74	Invertebrates, seeds
Total	776	14,689	2,507	

Table 2.8. Migratory diving duck species and abundance during fall, winter, and spring (2016/2017) observed in the Lower Green Bay and Fox River Area of Concern. Diet data gleaned from the Cornell Lab of Ornithology webpage (www.allaboutbirds.org).



	Abundance (2016/2017)			Primary Diet (varies with season)
	Fall	Winter	Spring	
Redhead	18	215	6,867	SAV, invertebrates, snails, zebra mussels
Ring-necked Duck	12	26	722	SAV, aquatic invertebrate
Canvasback	3	438	3,739	SAV, aquatic invertebrate
Greater Scaup	5,438	10,138	45,548	Clams, snails, crustaceans, aquatic insects, seeds, and aquatic plants
Lesser Scaup	913	2,283	15,003	Clams, snails, crustaceans, aquatic insects, seeds, and aquatic plants
Unidentified Scaup	42,303	22,505	133,238	Clams, snails, crustaceans, aquatic insects, seeds, and aquatic plants
Surf Scoter	12	0	1	Freshwater invertebrates, especially mollusks
White-winged Scoter	4	0	0	Mollusks, crustaceans, insects; aquatic plants, fish
Black Scoter	11	0	0	Aquatic invertebrates
Ruddy Duck	7,707	25	4,401	Aquatic insects, crustaceans, zooplankton; aquatic plants, seeds
Bufflehead	225	28	344	Aquatic invertebrates, crustaceans, and mollusks
Common Goldeneye	10,228	32,710	42,812	Aquatic invertebrates, crustaceans, mollusks fishes; seeds and tubers
Hooded Merganser	28	17	91	Small fish, aquatic insects, crustaceans, amphibians, vegetation, and mollusks
Common Merganser	167	17,036	3,050	Fish; aquatic invertebrates
Red-breasted Merganser	5,807	771	3,671	Fish; crustaceans, insects, tadpoles
Long-tailed Duck	5		1,542	Aquatic invertebrates, fish, fish eggs, and plants
Unidentified Duck	19,139	7,479	33,853	
Total	92,020	93,671	294,882	

Table 2.9. Migratory goose, swan, grebe, loon, and American Coot species and abundance during fall, winter, and spring (2016/2017) observed in the Lower Green Bay and Fox River Area of Concern. Diet data gleaned from the Cornell Lab of Ornithology webpage (www.allaboutbirds.org).

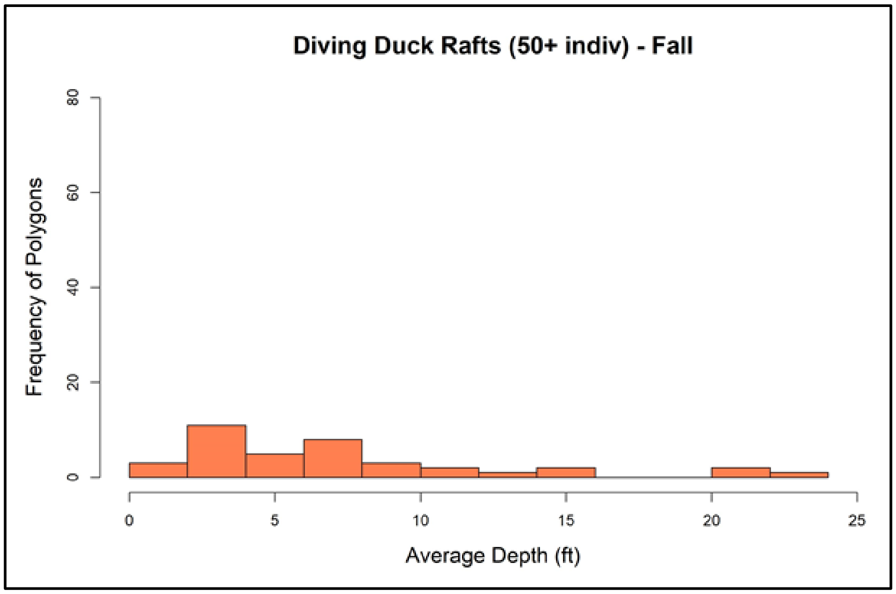
Other Species	**Type**	**Abundance (2016/2017)**			**Primary Diet**
		Fall	**Winter**	**Spring**	
Ross's Goose	Goose	2	0	0	Plants
Canada Goose	Goose	3,352	2,209	929	Plants
Tundra Swan	Swan	2	22	267	Plants
Trumpeter Swan	Swan	0	0	2	Plants
Pied-billed Grebe	Grebe	333	0	20	Crustaceans, small fish
Red-necked Grebe	Grebe	1	0	0	Fish, crustaceans, aquatic insects, mollusks
Horned Grebe	Grebe	241	5	310	Aquatic insects, fish, crustaceans, and other small aquatic animals.
Eared Grebe	Grebe	3	0	0	Aquatic invertebrates
Common Loon	Loon	113	2	7	Fish
Red-throated Loon	Loon	2		1	Fish
Pacific Loon	Loon	1			Fish and aquatic invertebrates
American Coot	Coot	4,522	152	419	Aquatic plant, insects, crustaceans, snails, small vertebrates
Total		8572	2390	1955	

Table 2.10. Diving duck comparison between the east and west shores in the Lower Green Bay and Fox River Area of Concern using a linear mixed-effects model: log(Diving Ducks+1) = (1|Site) + Season + Location + Season*Location (R function "lmer").

	East	**West**
Fall	1674 ± 521	321 ± 88
Spring	2644 ± 805	1465 ± 434

Table 2.11. Marsh (dabbling) duck comparison between the east and west shores in the Lower Green Bay and Fox River Area of Concern using a linear mixed-effects model: log(Diving Ducks+1) = (1|Site) + Season + Location + Season*Location.

	East	**West**
Fall	13.8 ± 2.9	9.9 ± 3.1
Spring	4.3 ± 2.8	67.5 ± 29.9



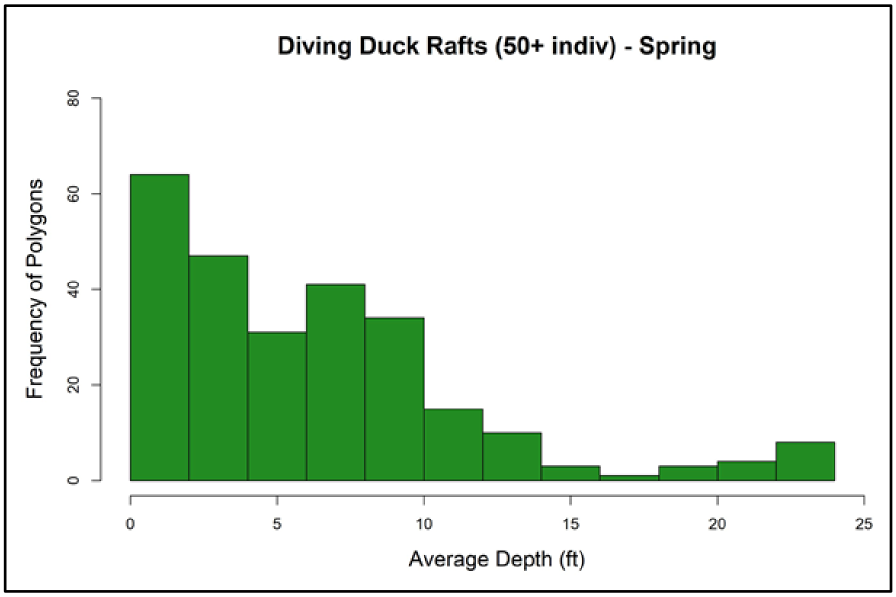


Figure 2.40. Seasonal distribution of diving duck rafts during fall (top) and spring (bottom) by the average water depth (ft). Diving duck rafts tend to occur in deeper water during fall.

Table 2.12. Results from an independent 2-group Mann-Whitney U Test based on diving ducks. Diving duck rafts tend to occur in deeper water during fall.

	Spring	Fall	p
Water depth (ft)	6.32	8.53	0.001
Raft size	1006.4	655.2	0.052
Distance to shore (m)	707.3	818.0	> 0.50

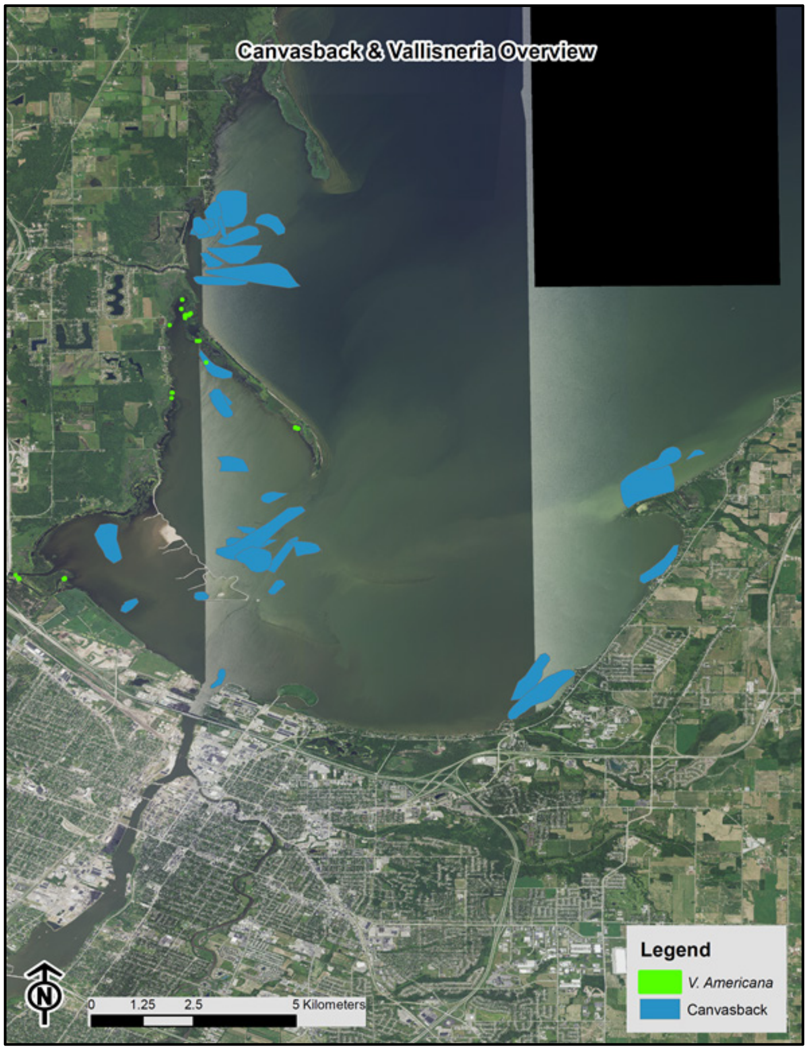


Figure 2.42. Overlay of *Vallisneria americana* (2017 surveys) locations and Canvasback rafts (2016/2017 surveys).

Migratory waterfowl: Common Goldeneye (left; taken by Scott Giese) and a resting Canvasback (right; taken by Erin Giese)

Bats

Wisconsin is home to eight species of bats, excluding the Indiana bat (*Myotis sodalis*), which was recorded only once in 1954, but including the evening bat (*Nycticeius humeralis*), newly documented in 2016. Four of Wisconsin's cave-roosting bats (big brown bat, *Eptesicus fuscus*; little brown bat, *Myotis lucifugus*; northern long-eared bat, *Myotis septentrionalis*; and tri-colored bat [eastern pipistrelle], *Perimyotis subflavus*) are listed as threatened in the state. All four of these have been recorded in the LGB&FR AOC study area, as have three of the other Wisconsin bats (silver-haired bat, *Lasionycteris noctivagans*; eastern red bat, *Lasiurus borealis*; and hoary bat, *Lasiurus cinereus*), known as "tree bats" because of their use of trees for roosting. In 2015 the northern-long-eared bat was listed as a federally threatened species under the U.S. Endangered Species Act. Silver-haired bat, while not endangered or threatened, is listed as "special concern" in Wisconsin and has a global rank of G3G4 (G3 = vulnerable, G4 = apparently secure) by NatureServe.

Populations of bats in Wisconsin and elsewhere in eastern North America are declining rapidly, partly due to a devastating disease (white-nose syndrome, WNS) caused by the fungus *Psuedogymnoascus destructans*. Between 2006 and 2008, cave bat declines exceeded 75% at surveyed hibernacula in eastern states (Blehert et al. 2009). WNS was first recorded in Wisconsin bats in 2016, and the threat of this epidemic (Langwig et al. 2015) has been the primary motivation for endangered/threatened listings of Wisconsin bat species that were, until recently, common and widespread in the state and throughout the Midwest. Other factors that have affected declines in tree-dwelling bats include mortality at wind turbines (Cryan and Barclay 2009) and habitat loss or degradation (Campbell et al. 1996, Crampton et al. 1998), and all bats may be vulnerable to the physiological effects of organic contaminants (Bayat et al. 2014).

Continued declines in Wisconsin bats may have severe ecological and perhaps even economic consequences. Boyles et al. (2011) estimated that insect predation by bats saves the U.S. agricultural industry $22.9 billion/year by preventing crop losses and reducing pest control expenses. The value of pest control by bats in managed forests has not been estimated, but it, too, must be worth billions of dollars annually. A single colony of 150 big brown bats consumes approximately 1.3 million insect pests each year, disrupting the population dynamics of species that otherwise would require expensive and often environmentally harmful control measures.

UW-Green Bay students Jeremiah Shrovnal and Jessica Kempke conducted acoustic bat surveys in the coastal zone of Green Bay during 2013 and 2016. Their results help set the stage for our assessment and recommendations for bat conservation in the LGB&FR AOC. Kempke's study using stationary bat detectors showed that two LGB&FR AOC sites, Barkhausen Waterfowl Preserve and Point au Sable, had frequent bat activity during both migration periods (spring and fall) and during summer. Stations located near the shoreline yielded consistently higher numbers of bats than stations located farther inland at Point au Sable and other localities outside the LGB&FR AOC, but not at Barkhausen. All seven of northeastern Wisconsin's native bats were recorded at Kempke's stations. Shrovnal sampled bats at standardized walking transects during June-September 2016 (Figure 2.43). Again, transects near the shoreline yielded more bat detections than transects located farther inland. West shore transects yielded higher bat numbers than transects from the east shore but transects along either shoreline were more productive than transects along the Fox River portion of the LGB&FR AOC (Figure 2.43). Big brown bat was by far the most frequently recorded species (Figure 2.43). Little brown bat, northern long-eared bat, hoary bat, red bat, and silver-haired bat were recorded regularly, even during summer, while tri-colored bat was positively identified at only two transects (Figure 2.43). The federally threatened northern long-eared bat was identified by Shrovnal at 18 different transects, but only after 20 July.

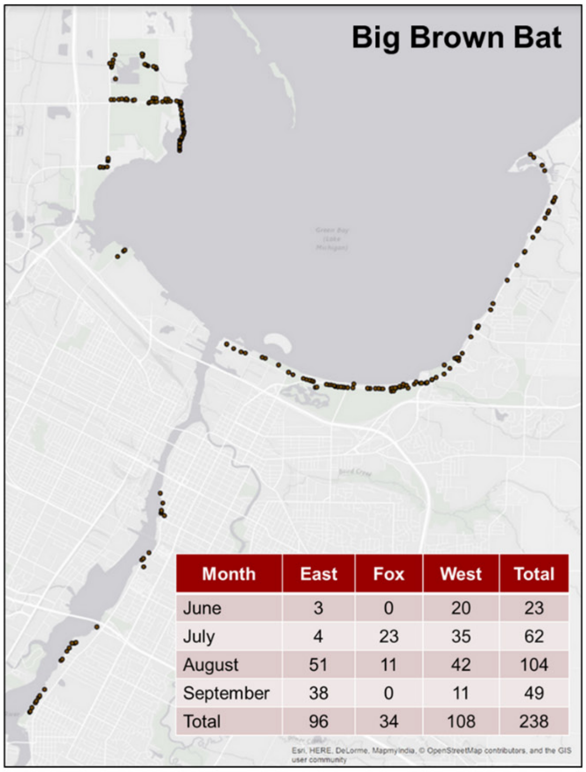
These studies show that the coastal zone of lower Green Bay is rich in bat activity, with evidence that five and possibly a significant sixth species (northern long-eared bat) are present as local summer residents as well as migrants.

Because they are not connected directly to the LGB&FR AOC aquatic ecosystem, bats are weighted in the lower quartile of species/species groups. Of course, their weighting of 11 is not far behind the highest score of 16 (for colonial waterbirds), so like other species groups, improvements in their condition will have a significant impact on the overall score for the fish and wildlife population BUI. We assigned a current condition of 4 for bats in the LGB&FR AOC based on the impending threat of WNS and the lack of documented hibernacula or roost sites in the coastal zone. We recommend future studies to identify critical areas for lower Green Bay and Fox River bats. Both Shrovnal and Kempke found particularly high numbers at the Barkhausen Waterfowl Preserve, so this area is a strong candidate for bat conservation efforts. The Bay Shore area at the UW-Green Bay campus also was heavily used by bats during Shrovnal's study. Urban Green Bay and developed suburbs are not strongly avoided by foraging bats, so the urban/suburban environment may play a significant role in bat conservation planning.

Langwig et al. (2017) recently found that heathy, persisting populations of little brown bat were much less likely to be affected by white-nose syndrome than populations that are declining. They conclude that disease resistance in healthy populations offers a "glimmer of hope" that North American bats may be able to survive the devastating effects of this deadly pathogen. Their conclusion implies that conservation of habitat and productive feeding areas for bats might be more important than ever.

We recommend an acoustic assessment method patterned after the transect surveys employed by Shrovnal in 2016. The method uses fixed length (500 m) walking surveys on calm, rainless evenings between sunset and midnight. Bat calls are recorded with a standard detector such as the Anabat Walkabout. The assessment metric is a multispecies index of ecological condition (IEC), which uses independent information about species' sensitivities to disturbance and a likelihood algorithm to calculate the condition score for a standardized field sample (Howe et al. 2007). Acquiring the species sensitivity functions (biotic response curves) will be needed in order to apply this method rigorously, although subjective functions based on expert opinion can be used in the absence of the appropriate background studies. The IEC score already uses a 0-10 scale, so the conversion curve is linear (Figure 2.44). Many areas are used by bats in the LGB&FR AOC. We recommend using an average IEC score from a minimum of 10 sites distributed in the best possible habitats known in the study area.

Conservation or restoration measures to improve the condition of bat populations in the LGB&FR AOC include protection of large trees and cavity trees for roosting of forest bats, identification and protection of roosting sites for "cave bats" in the vicinity of the lower bay and Fox River (possibly including artificially constructed "bat houses"), and protection of known feeding areas by restricting construction of wind turbines and other potential hazards. Ongoing assessment of bat populations in the LGB&FR AOC will be important to identify specific feeding areas and to follow the status of populations in light of threats by WNS syndrome and perhaps other emerging infectious diseases.



Big Brown Bat

Month	East	Fox	West	Total
June	3	0	20	23
July	4	23	35	62
August	51	11	42	104
September	38	0	11	49
Total	96	34	108	238

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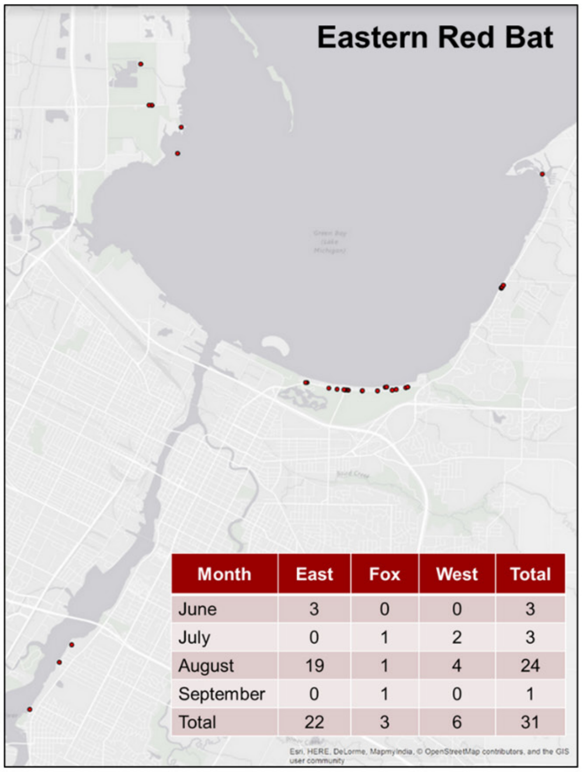

Eastern Red Bat

Month	East	Fox	West	Total
June	3	0	0	3
July	0	1	2	3
August	19	1	4	24
September	0	1	0	1
Total	22	3	6	31

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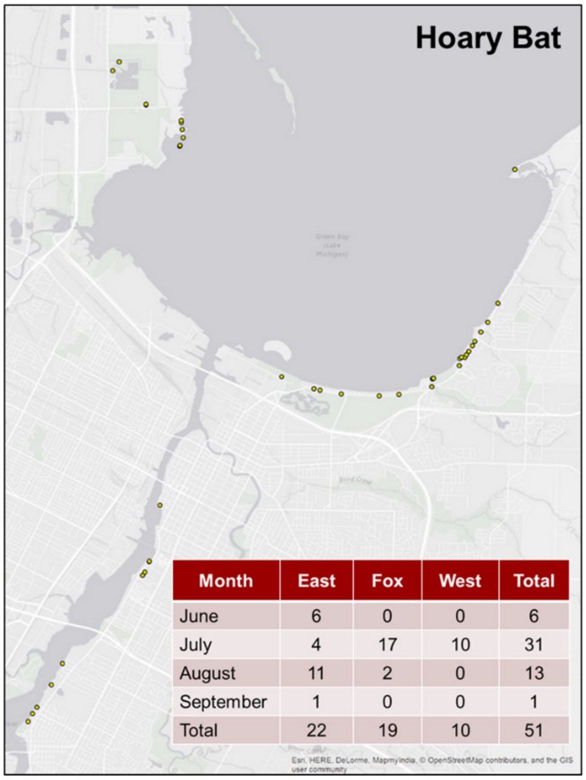

Hoary Bat

Month	East	Fox	West	Total
June	6	0	0	6
July	4	17	10	31
August	11	2	0	13
September	1	0	0	1
Total	22	19	10	51

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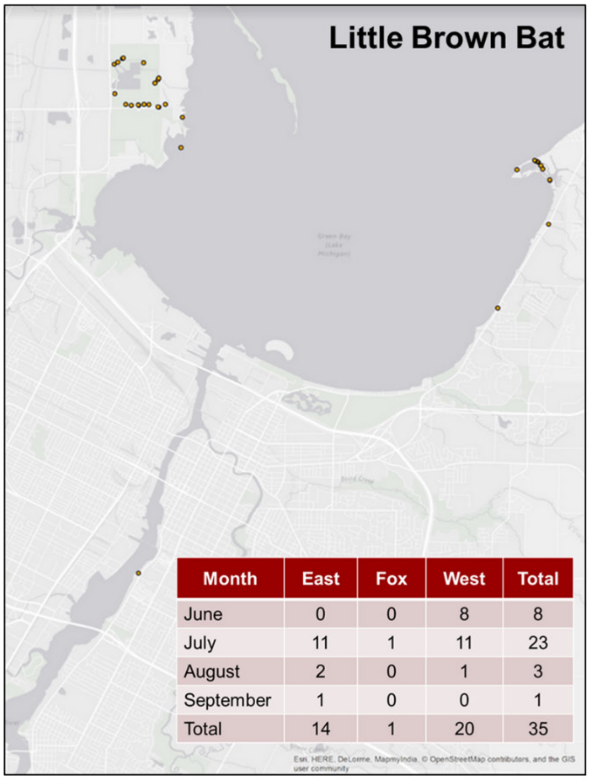

Little Brown Bat

Month	East	Fox	West	Total
June	0	0	8	8
July	11	1	11	23
August	2	0	1	3
September	1	0	0	1
Total	14	1	20	35

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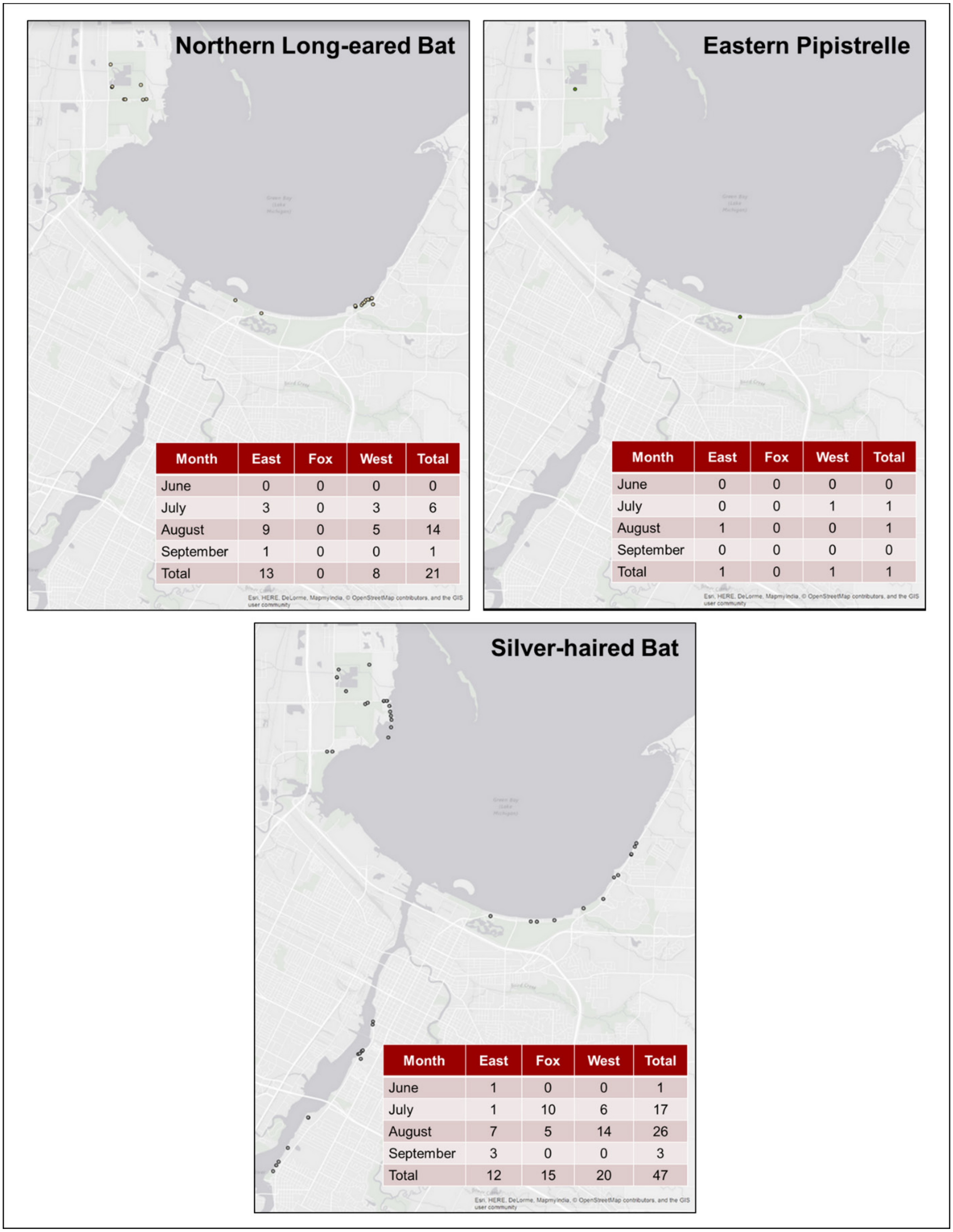

Northern Long-eared Bat

Month	East	Fox	West	Total
June	0	0	0	0
July	3	0	3	6
August	9	0	5	14
September	1	0	0	1
Total	13	0	8	21

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Eastern Pipistrelle

Month	East	Fox	West	Total
June	0	0	0	0
July	0	0	1	1
August	1	0	0	1
September	0	0	0	0
Total	1	0	1	1

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Silver-haired Bat

Month	East	Fox	West	Total
June	1	0	0	1
July	1	10	6	17
August	7	5	14	26
September	3	0	0	3
Total	12	15	20	47

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Figure 2.43. Bat detections based on surveys conducted in June-September 2016 along the east and west shores and along the Fox River within the Lower Green Bay and Fox River Area of Concern. Bat surveys and analysis conducted by Jeremiah Shrovnal. Map created by Jordan Marty in ArcGIS 10.5 (Environmental Research Systems Institute 2016). Basemap sources: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community.

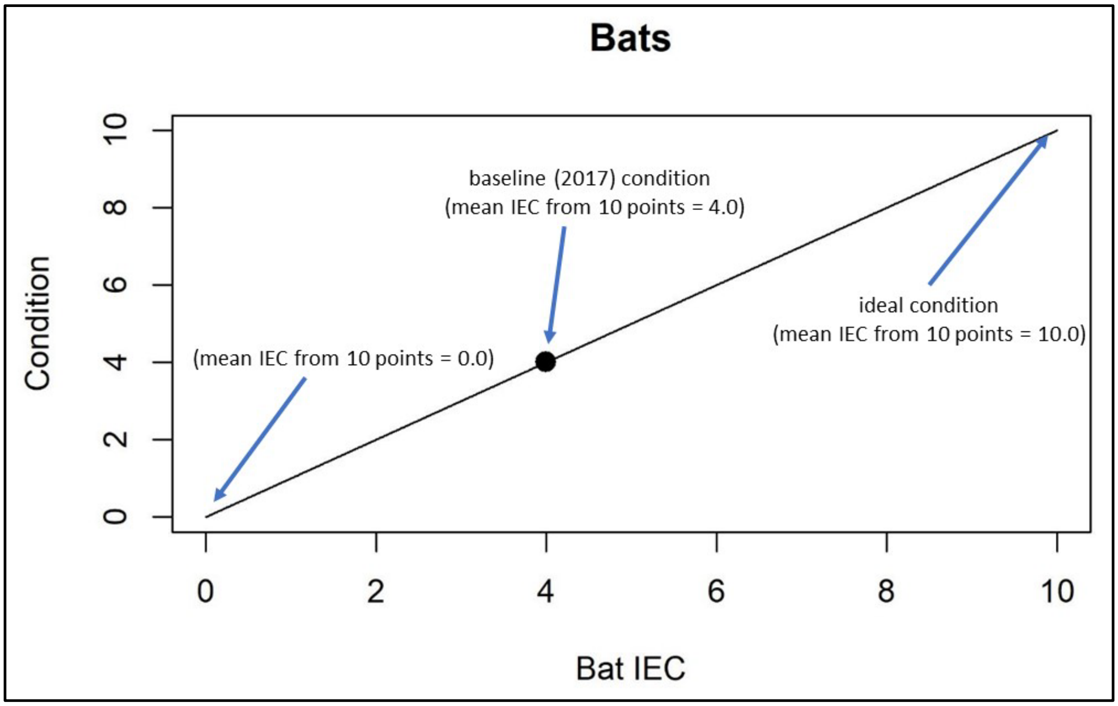


Figure 2.44. Bat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the bat IEC metric (scaled from 0 [no bats] to 10 [abundant bats]), which is determined through field surveys, and the y-axis is the converted condition for a given bat metric score, which ranges from poor condition (0) to good/ideal condition (10).

Bats: Little brown bat (left; taken by Erin Giese) and sample field surveys (right).

Coastal Wetland Aquatic Macroinvertebrates

Invertebrate communities of Great Lakes coastal wetlands are diverse and complex, including open water zooplankton, bottom-dwelling zoobenthos, epiphytic invertebrates (attached to vegetation and other objects), and surface-dwelling neuston (Krieger 1992). Even for conspicuous macroinvertebrates, large knowledge gaps exist, and an in-depth assessment of species assemblages would be prohibitively expensive and beyond the capacity of available expertise. Assessment and monitoring of wetland macroinvertebrates is further complicated by the fact that most species undergo developmental metamorphosis, where the ecology of juveniles and subadults is very different from that of adults.

Despite these challenges, standardized sampling protocols have been developed that can differentiate degraded vs. relatively pristine macroinvertebrate communities in Great Lakes coastal wetlands (Burton et al. 1999, Kashian and Burton 2000, Uzarski et al. 2017). Burton et al. (1999) recognized that, regardless of environmental stress, macroinvertebrates vary significantly among different wetland vegetation zones, including outer and inner zones dominated by rushes (*Scirpus*/*Schoenoplectus* spp.), emergent marsh dominated by *Typha* spp., and wet meadow dominated by *Carex* spp. and *Calamagrostis* spp. (southern sedge meadow). Their research team developed different index of biotic integrity (IBI) metrics for each zone, recommending an average among zones for an overall wetland indicator. Uzarski et al. (2004) and Uzarski et al. (2017) further improved these IBI metrics. The field sampling methods recommended by Burton, Uzarski, and colleagues consist of dip net collections followed by systematic identification of a fixed number of individuals.

The IBI metrics of Burton et al. (1999) and others employ community variables like overall taxonomic richness or counts of individuals within broad groups such as Crustacea + Mollusca, Odonata, and Isopoda. In many cases, these variables showed different responses to disturbances in different vegetative zones, and subsequent studies (e.g., Great Lakes Environmental Indicator Project; Ciborowski et al. 2015) have shown that species within the groups often exhibit different responses to environmental stress. Nevertheless, several taxonomic groups, notably genera or families of Odonata (dragonflies and damselflies), mayflies (Ephemeroptera), and Sphaeridae (fingernail clams), show consistent sensitivity to environmental stress. Burton et al. (1999) also found that total taxonomic richness was consistently associated negatively with environmental stress in the *Typha* and inner *Scirpus*/*Schoenoplectus* zones of Great Lakes wetlands, a result that is consistent with the Great Lakes Environmental Indicator results (R. Howe, *pers. comm.*) that many taxa (e.g., *Notonecta* [backswimmers], *Planorbella* [a snail]) decrease or disappear at heavily stressed sites.

Our definition of “coastal wetland aquatic macroinvertebrates” excludes species assemblages of the outer *Scirpus*/*Schoenoplectus* (bulrush) zone, which is absent from the edge of many wetlands in the LGB&FR AOC. Wet meadows also are rare or highly degraded in the LGB&FR AOC, so we excluded this zone, at least for this report. Hence, our analysis of coastal wetland aquatic macroinvertebrates refers to macroinvertebrates of the inner *Scirpus*/*Schoenoplectus* and *Typha* zones, where relatively tall emergent wetland plants are dominant.

From May through October 2016, UW-Green Bay graduate student Willson Gaul conducted surveys of Odonata at seven sites within the LGB&FR AOC and one (Sensiba State Wildlife Area) site just north of Long Tail Point. During 107 hours of field sampling, he identified 38 species (Table 2.13). Difficult species identifications were confirmed by WDNR Odonata expert Robert DuBois. Observations for which species identification was uncertain were excluded when making this list. Sampling locations consisted of fixed length transects plus an area of approximately 1.61 km radius around the transect locations. Only two of the recorded species (green-striped darner, *Aeshna verticalis* and russet-tipped clubtail, *Stylurus plagiatus*) are listed as vulnerable (state rank = S3 and S3S4, respectively) in Wisconsin. Highest species richness (18 species) was recorded at the Sensiba State Wildlife Area reference site, followed closely by Point au Sable (17 species) and the Cat Island Chain Restoration Site (13 species).

Because of the low economic importance and lack of endangered/threatened status for species of the LGB&FR AOC, coastal wetland aquatic macroinvertebrates were weighted in the lowest quartile of species/species groups (weight = 11). Gaul’s Odonata study and general results from the Great Lakes Coastal Wetland Monitoring Program led us to assign a baseline condition of 3 (on a scale of 0-10) for this group in the LGB&FR AOC. This estimate could be pessimistically low, but without additional information, we have little justification for assigning a higher value except for the fact that the Odonata diversity is far from 0 species at all but a few sites.

Future studies will be needed to develop a locally relevant assessment metric based on the sampling scheme of Uzarski et al. (2017). The prescribed field method uses dip nets at three or more points within a given wetland in the inner *Scirpus/Schoenoplectus* and *Typha* zones. Sampling should be conducted during late summer to maximize vegetation structure and invertebrate life stages (Uzarski at al. 2017). We suggest that a narrow range of taxa (e.g., all Odonata, Ephemeroptera, selected aquatic Hemiptera and Coleoptera, etc.) be collected and counted so that identification is accurate and cost effective. The quantitative metric itself should be derived from sites in Green Bay, but reference localities outside the LGB&FR AOC should be used to help calibrate the response of species to ecological stress. Results from the Uzarski et al. (2017) field methods lend themselves to the index of ecological condition (IEC) approach of Howe et al. (2007) and Gnass Giese et al. (2015), calibrated to the baseline condition of 3 (Figure 2.45) on a 0-10 scale. In order to construct the IEC metric, we will need to identify a manageable assemblage of sensitive taxa and plot the response of these taxa to an environmental stressor gradient. Existing data from the Great Lakes Coastal Wetland Monitoring Program provide an excellent foundation for identifying locally or potentially occurring sensitive species. Overall condition of the LGB&FR AOC with respect to aquatic macroinvertebrates can be estimated by averaging IEC scores from 10 or more sample locations.

Conservation actions to elevate the condition of coastal wetland aquatic macroinvertebrates include measures to 1) improve wetland water quality, 2) control invasive species like *Phragmites*, 3) construct or restore favorable substrates (e.g., submerged rock piles) for immature stages of target species, and perhaps 4) reintroduce locally extirpated species such as the mayfly (*Hexagenia bilineata*; Groff and Kaster 2017).

Table 1.13: Odonate species in the LGB&FR AOC in 2016, ordered approximately from most to least abundant within the LGB&FR AOC and 1 km inland buffer. Codes: r = rare – species observed only once at this site; uc = uncommon – between 2 and 10 individuals observed at this site, or species observed between 2 and 10 occasions; c = common – 10 or more individuals observed at this site; x = present – survey effort was insufficient to determine how common or abundant this species was at this site. Table compiled by Willson Gaul.

Species	Common Name	Ashwaubomay River Park	Cat Island Chain Restoration Site	Dead Horse Bay	East River Park	Long Tail Point	Point Sable	Sensiba	UWGB Arboretum
Eastern Forktail	*Ischnura verticalis*	x	c	c	x	x	c	c	c
Sedge Sprite	*Nehalennia irene*						c	c	r
Slender Spreadwing	*Lestes rectangularis*	x	uc				c	uc	uc
Taiga Bluet	*Coenagrion resolutum*		uc				c	c	
Autumn Meadowhawk	*Sympetrum vicinum*		c			x	c	uc	c
Dot-tailed Whiteface	*Leucorrhinia intacta*		r				uc	c	uc
Common Green Darner	*Anax junius*	x	c	c			c	c	c
Twelve-spotted Skimmer	*Libellula pulchella*		uc	x			uc	c	c
Tule Bluet	*Enallagma caunculatum*	x	uc	uc		x	uc	uc	
Marsh Bluet	*Enallagma ebruim*						uc	uc	c
Four-spotted Skimmer	*Libellula quadrimaculata*		uc				c	uc	
White-faced Meadowhawk	*Sympetrum obtrusum*		uc	x			uc	uc	uc
Hagen's Bluet	*Enallagma hageni*						uc	uc	
Black Saddlebags	*Tramea lacerata*		r	uc			r	uc	uc
Blue Dasher	*Pachydiplax longipennis*		uc	c	x		r	r	
Eastern Amberwing	*Perithemis tenera*	x		c	x		uc		
Lance-tipped Darner	*Aeshna constricta*		uc				c		r
Chalk-fronted Corporal[1]	*Ladona julia*							uc	
Eastern Pondhawk	*Erythermis simplicicollis*			c				uc	uc
Halloween Pennant	*Celithemis eponina*			c				uc	
Racket-tailed Emerald	*Dorocordulia libera*						uc	uc	
Wandering Glider	*Pantala flavescens*		uc						uc
Spotted Spreadwing	*Lestes congener*						uc		r
Ebony Jewelwing[1]	*Calopteryx maculate*								c
Spot-winged Glider[1]	*Pantala hymenaea*		uc						
Blue-fronted Dancer	*Argia apicalis*	x					uc		

Ruby Meadowhawk	*Sympetrum rubicundulum*						r		r
Band-winged Meadowhawk	*Sympetrum semicinctum*		r						r
Belted Whiteface[1]	*Leucorrhinia proxima*							uc	
Orange Bluet	*Enallagma signatum*				x		r		
Emerald Spreadwing[1]	*Lestes dryas*						r		
Beaverpond Baskettail[1]	*Epitheca canis*							r	
Common Whitetail[1]	*Plathemis lydia*								uc
Familiar Bluet[1]	*Enallagma civile*		r						
Shadow Darner[1]	*Aeshna umbrosa*						r		
Widow Skimmer[1]	*Libellula luctuosa*						r		
Green-striped Darner[1,2] **(S3)**	*Aeshna verticalis*		r						
Russet-tipped Clubtail[1,2] **(S3S4)**	*Stylurus plagiatus*	x							

Species with a Wisconsin State Rank of S3 or lower (indicating vulnerable status) are indicated above. Explanation of WI State Rank Codes can be found at: www.dnr.wi.gov/topic/NHI/WList.html#SRank.

Observed at only one site within the AOC.
[2] WI State Rank of S3 (vulnerable in WI)

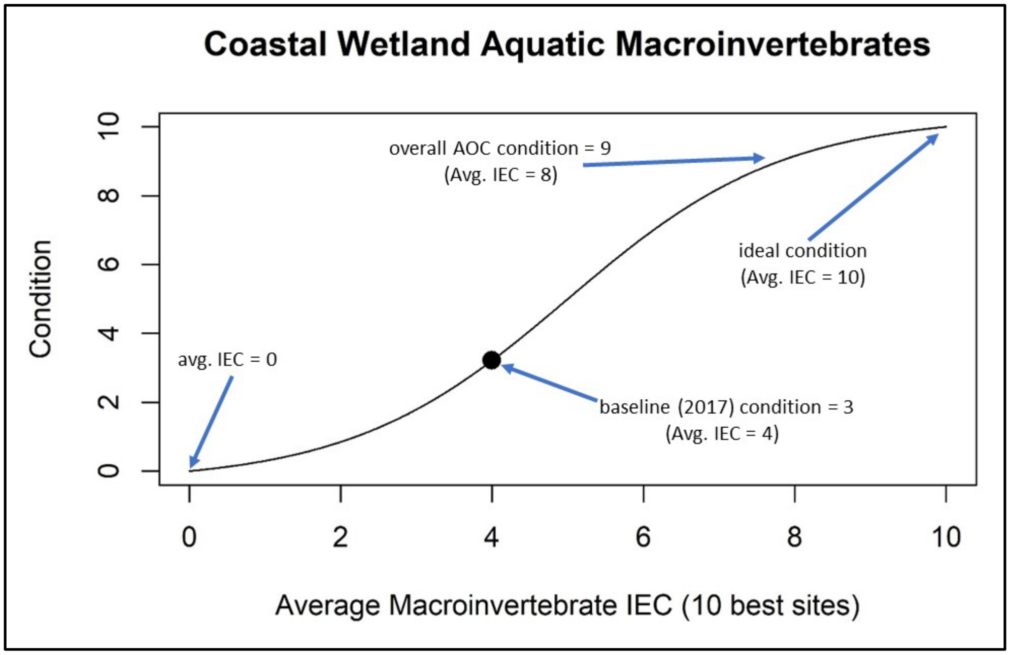


Figure 2.45. Coastal wetland aquatic macroinvertebrates assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the average IEC value (scaled from 0 [no macroinvertebrates] to 10 [ideal condition]), which is determined through field surveys, and the y-axis is the converted condition for a given IEC score, which ranges from poor condition (0) to good/ideal condition (10).

Coastal wetland aquatic macroinvertebrates: orange bluet (left) and mayfly (right; family Ephemeroptera), taken by Robert Howe.

Stream Macroinvertebrates

Several small tributaries enter lower Green Bay and the Fox River within the LGB&FR AOC boundary (e.g., Wequiock Creek, Mahon Creek, Ashwaubenon Creek). Although the hydrologic discharge from these watercourses is miniscule compared with the water flowing into the bay from the Fox River and, to a lesser extent, Duck Creek, these streams provide important fish and wildlife habitat and deserve to be a part of LGB&FR AOC restoration efforts. Water quality in these streams is often better than that of the highly eutrophic and sediment-laden lower bay, Fox River, and main channel of Duck Creek. Given the continuing water quality issues in this ecosystem, small tributaries may serve as refugia for ecologically sensitive invertebrates and as critical habitats for spawning or juvenile development of certain LGB&FR AOC fishes. Stream invertebrates also are sensitive to the effects of climate change (Hogg et al. 1996), and trends in species composition may provide evidence of broader ecosystem changes not directly attributable to the local environment.

Stream macroinvertebrates are important because they are a food source for fishes, but they also influence other attributes of stream ecosystems including nutrient cycling, decomposition, patterns of primary productivity, and translocation of biomass (Wallace and Webster 1996). Stream macroinvertebrate communities themselves are affected by many factors, including the regional species pool, physical stream morphology, and species interactions (Heino and Peckarsky 2014). Despite the well-documented ecological significance of stream macroinvertebrate communities, we weighted stream macroinvertebrates in the lower quartile of species/species groups, largely because of their low economic importance and the limited extent of stream habitats in the LGB&FR AOC.

Numerous studies have demonstrated that certain macroinvertebrates, particularly species in the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), are sensitive to pollution and can be used to assess the ecological condition of stream ecosystems (Lydy et al. 2000, Herman and Nejadhashemi 2015). Development of stream macroinvertebrate indicator metrics has been pioneered in Wisconsin, so details about the environmental sensitivities of local species are fairly well documented. Hilsenhoff (1987, 1998) assigned pollution tolerance values ranging from 0 (low tolerance to pollution) to 10 (high tolerance to pollution) for more than 400 species or genera of stream macroinvertebrates found in rock or gravel riffles of wadable streams in the western Great Lakes. He outlined a systematic sampling method for collecting and identifying samples of 100 or more individuals from a single riffle section of the stream. The Hilsenhoff Biotic Index (HBI) is simply the average tolerance value of all individuals collected in a sample, or the average of HBI values from multiple riffles sampled in a stream. Kerans and Karr (1994) introduced an alternative metric, the Benthic Index of Biotic Integrity (B-IBI), which uses three types of variables: taxonomic richness in certain categories (e.g., species richness of intolerant snail and mussel species; species richness of mayflies), proportion of individuals in certain taxonomic categories (e.g., proportion individuals that are oligochaetes), and proportion individuals in important functional groups (e.g., proportion of individuals that are shredders). These variables were calibrated at pristine reference sites, a critical step in the development of any rigorous assessment metric, including the HBI (Whittier et al. 2007). Although the B-IBI incorporates several different types of community and taxonomic variables, the relationships and degree of redundancy among these variables are unknown and therefore complicate the interpretation of this index. We suggest that the simple HBI, which also includes redundancy and highly subjective variables (species' tolerance values), be used until a more objective metric is developed. In order to construct an assessment metric that applies to the entire LGB&FR AOC, measurements from multiple streams need to be combined in some way. We recommend applying an average of HBI or similar metric for the 5 best watercourses, averaged and converted to our standard scale from 0 (worst condition) to 10 (Figure 2.46).

Ten small watercourses draining into the LGB&FR AOC can be reasonably classified as streams. Four of these are on the east shore: Wequiock Creek, Seminary Creek, Barina Parkway, and Mahon Creek. Four slow-moving watercourses on the west shore may qualify as streams, at least during parts of the year: an unnamed tributary flowing into the wetland north of Duck Creek, just west of I-41; an intermittent watercourse through Fort Howard Wildlife Area/Barkhausen Waterfowl Preserve; and two highly modified channels traversing the Malchow/Olson Tract and Barkhausen properties. Two larger and highly impacted tributaries, Ashwaubenon Creek and Dutchman's Creek, flow into the Fox River. Only about half of these 10 watercourses are permanently flowing with riffles and pools typical of natural streams.

High school students, educators, and volunteers have collected aquatic macroinvertebrates from Ashwaubenon Creek, Dutchman's Creek, Duck Creek, and Wequiock Creek as part of the Lower Fox River Watershed Monitoring Program (https://www.uwgb.edu/watershed/data/habitat-biota.asp). Results indicate poor to fair conditions, translated by us into an overall baseline condition of 4 (where 0 = poorest condition and 10 = best attainable condition) for stream invertebrates in the LGB&FR AOC.

Pollution abatement upstream clearly is important for improving the condition of stream macroinvertebrates, but restoration of in-stream habitat also is needed for many if not all small tributaries in the LGB&FR AOC. Published studies provide a wealth of general guidance for ecological restoration of impaired streams (e.g., Roni et al. 2002, Bernhardt and Palmer 2007). Effective management actions include 1) improving stream connectivity by removing dams and other barriers (Jansson et al. 2007), 2) restoring substrate features like gravel/sand riffles or woody debris (Larson et al. 2001, Schwartz and Herricks 2007), 3) restoring natural stream hydrology by reconstructing meanders, pools, backwaters, and other features lost through channelization (Rinaldi and Johnson 1997, Kondolf 2006), and 4) rehabilitating streambank and riparian features by re-vegetation or bank stabilization (Sudduth and Meyer 2006). Kitto et al. (2015), Swan and Brown (2017), and others have noted that physical changes in habitat do not always improve stream biodiversity because many native species are dispersal-limited, unable to rapidly recolonize stream segments where they have been locally extirpated. By the same token, quality upstream habitats might function as biological refugia, harboring native invertebrates that might recolonize restored sites downstream or even in the bay or Fox River.

In summary, efforts to improve the condition of stream macroinvertebrates may have accompanying benefits for tributary fishes, coastal invertebrates, freshwater unionid mussels, and perhaps other target habitats or populations. Given the relatively low baseline condition and wealth of guidance for stream restoration measures, investments in this feature of the LGB&FR AOC likely will contribute significantly to successful BUI removal.

Local volunteers sampling physical attributes of Wequiock Creek and the Point au Sable Nature Preserve.

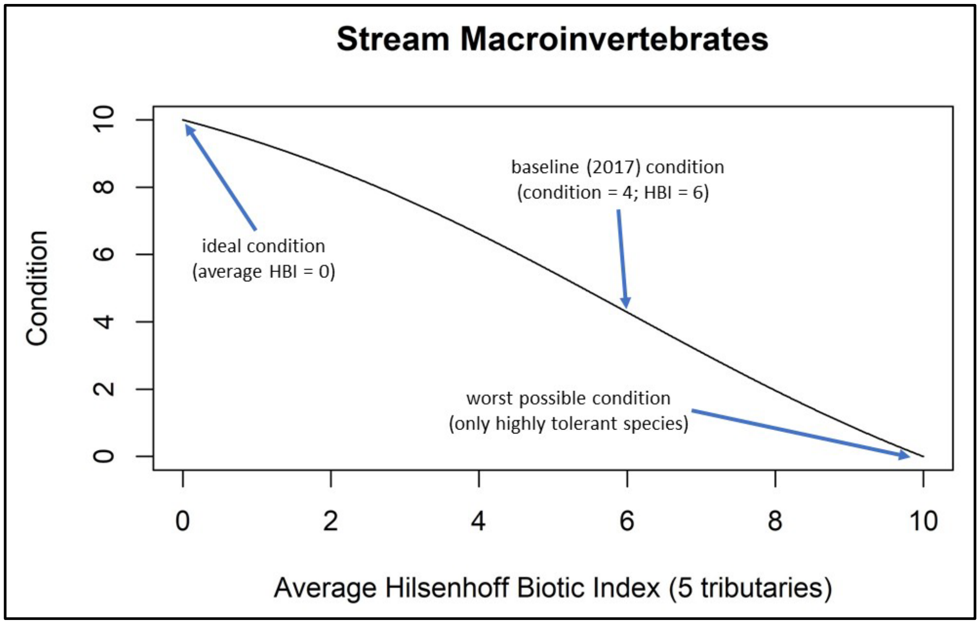


Figure 2.46. Conversion curve for converting average Hilsenhoff Biotic Index (HBI) of stream invertebrates in 5 best LGB&FR AOC tributaries into condition score ranging from 0 (poor) to 10 (ideal, good condition).

Turtles

The original BUI removal targets for the LGB&FR AOC (Wisconsin Department of Natural Resources 2016a) proposed that reptiles (including snapping and painted turtles) should be sustained in “abundances sufficient to provide ecological function.” Assuming that turtles have been an integral part of the historically recent (~500 yr ago to present) Green Bay ecosystem, maintenance of viable turtle populations in the LGB&FR AOC implies that their ecological function is at least partially fulfilled. Presence of viable populations themselves, unfortunately, are not clearly established today. We observed few turtles of any kind during our field surveys, although of course the methods were not targeted toward this group. Nevertheless, this is a group that we suggest deserves increased attention.

Two widespread species, eastern snapping turtle (*Chelydra serpentina*) and painted turtle (*Chrysemys picta*), are by far the most common turtles in the LGB&FR AOC. Additionally, Blanding’s turtle (*Emydoidea blandingii*), recently delisted as a Wisconsin threatened species, has been reported in Brown County (Wisconsin Herp Atlas Project 2007). Suitable habitat (Ross and Anderson 1990) occurs in coastal landscapes such as Point Sable, Bay Beach Wildlife Sanctuary, Duck Creek Delta, Barkhausen Waterfowl Preserve, and the Malchow/Olson Tract, where mosaics of ponds, forested swamps, and wet meadows are located near the Green Bay shoreline (Joyal et al. 2001). Spiny softshell turtle (*Apalone spinifera*) has been verified in Brown County (Wisconsin Herp Atlas Project 2007), including in the lower Fox River in the 1980s (G. Casper, *pers. comm.*), and was found in the bay south of Point Sable in 2015 (S. Beilke, *pers. comm.*). Wood turtle (*Glyptemys insculpta*), officially listed as threatened in Wisconsin, favors forested streams with nearby wet meadows (Compton et al. 2002). This species may not be present in the coastal zone of Green Bay but has been found in Duck Creek and Pensaukee (G. Casper, *pers. comm.*) and could potentially occur at other sites along the East River or Baird Creek.

Turtles are weighted in the lower middle quartile of species/species groups based on the assumption that both Blanding’s turtle and wood turtle are extirpated from the LGB&FR AOC. Reintroduction of either species could elevate the ranking due to their state and global status. Despite the fact that Blanding’s turtle was delisted in 2014, it is still a species of special concern and has a global NatureServe ranking of G4 (http://explorer.natureserve.org/granks.htm). Several recent studies, including Smith et al. (2016), have demonstrated that turtles, especially long-lived species like snapping turtle and Blanding’s turtle, concentrate toxic heavy metals in their tissues and may be valuable species for monitoring environmental contaminants.

Although aquatic traps are often used for inventorying and monitoring turtles, we recommend a metric based on time-limited (4 hr maximum) visual surveys during late spring and early summer when vegetation growth is minimal, and visibility is maximized. Surveys can be conducted from kayaks/boats or at strategic observation points located 500 m or more apart (Marchand and Litvaitis 2004, Quesnelle et al. 2013). By-catch from fish surveys (e.g., Wieten et al. 2012) and periodic trap surveys can be used to validate results from the visual surveys, which are relatively inexpensive and can be repeated frequently and at many locations. All four likely-occurring species (painted turtle, eastern snapping turtle, Blanding’s turtle, and eastern spiny softshell turtle) are known to bask regularly during late spring or early summer (e.g., Obbard and Brooks 1979, Millar and Blouin-Demers 2011), although basking sites appear to be least important for spiny softshell turtles (DonnerWright et al. 1999).

We present a simple metric, T (Figure 2.47), that incorporates both species richness and turtle abundance, where T = $\sum_{k=1}^{4} a_k$, a = number of sites (separated by at least 500 m), and species k was observed during standard surveys in optimal basking conditions; the maximum value for any single species is limited to 5. An ideal condition (10) occurs when at least 4 species of turtles are observed at 5 or more sites (T = 20). This somewhat unlikely condition is mitigated by the non-linear curve, which yields a condition of >8.0 when only 3 species are regularly observed (T = 15) and approximately 7 when two species are observed at the maximum 5 sites.

We have little information about the current status of turtles in the LGB&FR AOC. Based on this fact, we assigned a conservative baseline condition score of 5.0, assuming that at least one turtle species is regularly observed in the LGB&FR AOC or two species are present at just a few localities each.

Wieten et al. (2012) demonstrated that submersed/submerged aquatic vegetation (SAV), waterlilies, cattails, and hydrologic features of drowned river mouths were associated with abundance of turtles at 56 coastal wetlands in Lakes Huron, Michigan, and Superior. Conservation of areas with extensive SAV and waterlilies (e.g., Duck Creek and Dead Horse Bay) will be important for improving the condition of turtles in the AOC. Threats from highway mortality and nest predation also need to be addressed. Surveys for locating nesting habitat may be combined with caging or fencing egg burial sites during the turtle incubation period.

Basking sites such as shoreline deadwood, sandbars, or vegetation islands have been shown to be critical for thermoregulation in turtles (Boyer 1965). These habitats are generally missing from developed shorelines in the LGB&FR AOC and should be an important element of proposed beach and shoreline restoration projects.

Translocation of Blanding's turtles at appropriate sites like Point au Sable, Bay Beach Wildlife Sanctuary, the Duck Creek Estuary, Barkhausen Waterfowl Preserve, and the Malchow/Olson Tract should be considered as a measure for increasing the condition of turtles in the LGB&FR AOC. All of these sites contain protected ponds for overwintering, wet meadow habitats, and sandy openings for nesting. Point au Sable and the Malchow/Olson Tract are also isolated from major roads, minimizing one of the major mortality threats. Translocation of Blanding's turtles has been successful in Massachusetts, particularly when individuals were "headstarted" by raising hatchling turtles in captivity for 9 months before release (Buhlmann et al. 2015). Because Blanding's turtles are long-lived and require 14-20 yr to reach sexual maturity (Congdon and van Loben Sels 1993), large numbers will need to be released to account for even modest juvenile and sub-adult mortality.

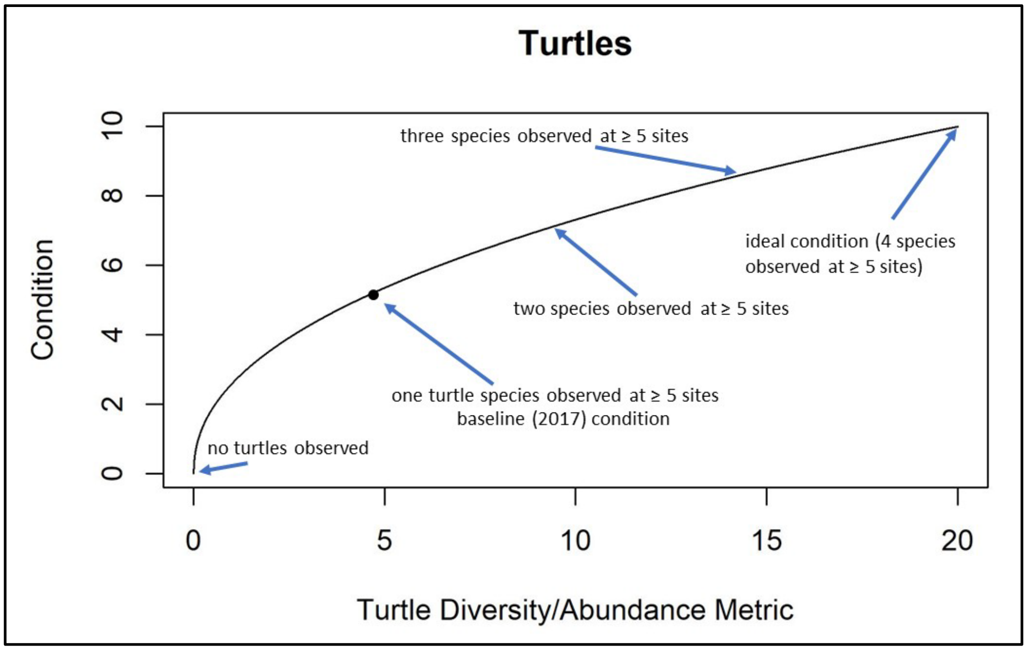
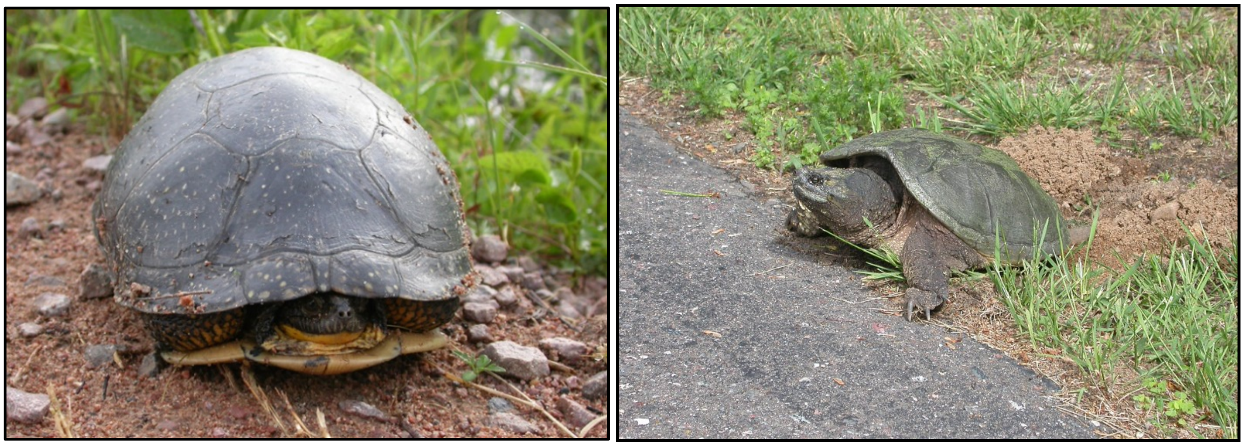


Figure 2.47. Turtle assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the diversity of turtles/abundance metric (scaled from 0 [no turtles] to 10 [ideal condition]), which is determined through field surveys, and the y-axis is the converted condition for a given turtle metric score, T, which ranges from poor condition (0) to good/ideal condition (10).



Turtles: Blanding’s turtle (left) and eastern snapping turtle (right). Photographs taken by Thomas Prestby.

Landbirds (migratory)

The “migratory landbirds” group consists of woodpeckers, cuckoos, nightjars, hummingbirds, and perching birds (Order Passeriformes) that use terrestrial habitats as migratory stopover habitat during spring or fall migration. Migratory landbirds often follow landmarks like the north-south shorelines of Green Bay, and at the end of long, daily or nightly flights they require critical habitat for refueling or resting (Diehl et al. 2003, Ewert et al. 2005, Bonter et al. 2009). Productive waterbodies like Green Bay also produce significant numbers of aquatic insects (e.g., midges [Chironomidae]) and other invertebrates, which provide much needed, protein-rich food sources for migratory landbirds (Smith et al. 1998, Bonter et al. 2009).

Although migratory landbirds are broadly abundant in the lower Green Bay coastal zone, we identify six important hotspots (Figure 2.48): 1) Point au Sable, 2) Bay Beach Wildlife Sanctuary West, 3) UW-Green Bay's Cofrin Arboretum, including Bay Shore Woods and Beach and Mahon Woods and Creek on the east shore, 4) Ken Euers Wildlife Area, 5) Barkhausen Waterfowl Preserve, and 6) the privately-owned Malchow/Olson Tract on the west shore (Important Bird Areas, Epstein et al. 2002, Beilke 2015, eBird 2017). All of these hotspots, except the UW-Green Bay sites, are included in one of two "Important Bird Areas," namely "Lower Green Bay Islands-Bay Beach Wildlife Sanctuary" and "Green Bay West Shore Wetlands" (Important Bird Areas webpage). These areas encompass critical migratory bird stopover habitats, such as emergent marsh, shrub carr, and both lowland and upland forest. These habitats provide refueling food sources, including fruiting shrubs and seeds in the fall and insects in the spring. Over 200 bird species have been reported at several lower Green Bay migratory landbird hotspots, though the number of species includes waterbirds, raptors, shorebirds, and other non-landbirds (eBird 2017). Because it is privately-owned, no long-term bird data are available from the Malchow/Olson Tract; however, this site comprises one of the highest quality and most diverse habitat mosaics in the LGB&FR AOC coastal zone. Migratory landbirds almost certainly utilize it extensively. State-listed special concern migratory landbirds, such as Golden-winged Warbler (*Vermivora chrysoptera*), Blue-winged Warbler (*Vermivora cyanoptera*), Cape May Warbler (*Setophaga tigrina*), Swainson's Thrush (*Catharus ustulatus*), and others, are regularly reported at migratory hotspots in the LGB&FR AOC coastal zone (eBird 2017).

Long-term research at Point au Sable by UW-Green Bay researchers has shown that this site clearly is a critical migratory landbird stopover site (Epstein et al. 2002), especially for warblers, sparrows, vireos, woodpeckers, and blackbirds (Beilke 2015). Shortly after dawn, we have witnessed migrant "fallouts" where thousands of small songbirds appear in the treetops. Presumably overnight migrants along or over Green Bay, these birds refuel along the shoreline and in or near the site's coastal wetlands before the next leg of their journey. Point Sable was recently listed as one of the most important sites for Rusty Blackbird (*Euphagus carolinus*) stopover habitat, the only site listed in the LGB&FR AOC coastal zone (Beilke 2015, International Rusty Blackbird Working Group 2015). Similarly, Bay Beach Wildlife Sanctuary West has long been recognized as an important migratory stopover site, especially for warblers (Important Bird Areas webpage). Year after year, bird watchers from northeastern Wisconsin and elsewhere spend hours watching spring migrants at this site, documented by extensive records at the Cornell Laboratory of Ornithology's eBird web site. Although the six migratory landbird hotspots support impressive concentrations of birds, migrants also use marginal, often small, habitat patches throughout the LGB&FR coastal zone (e.g., Fox River Trail, suburban yards). Bird-friendly landscapes undoubtedly contribute significantly to successful bird migration throughout the region (S. Beilke and E. Giese, *pers. comm.*, eBird 2017).

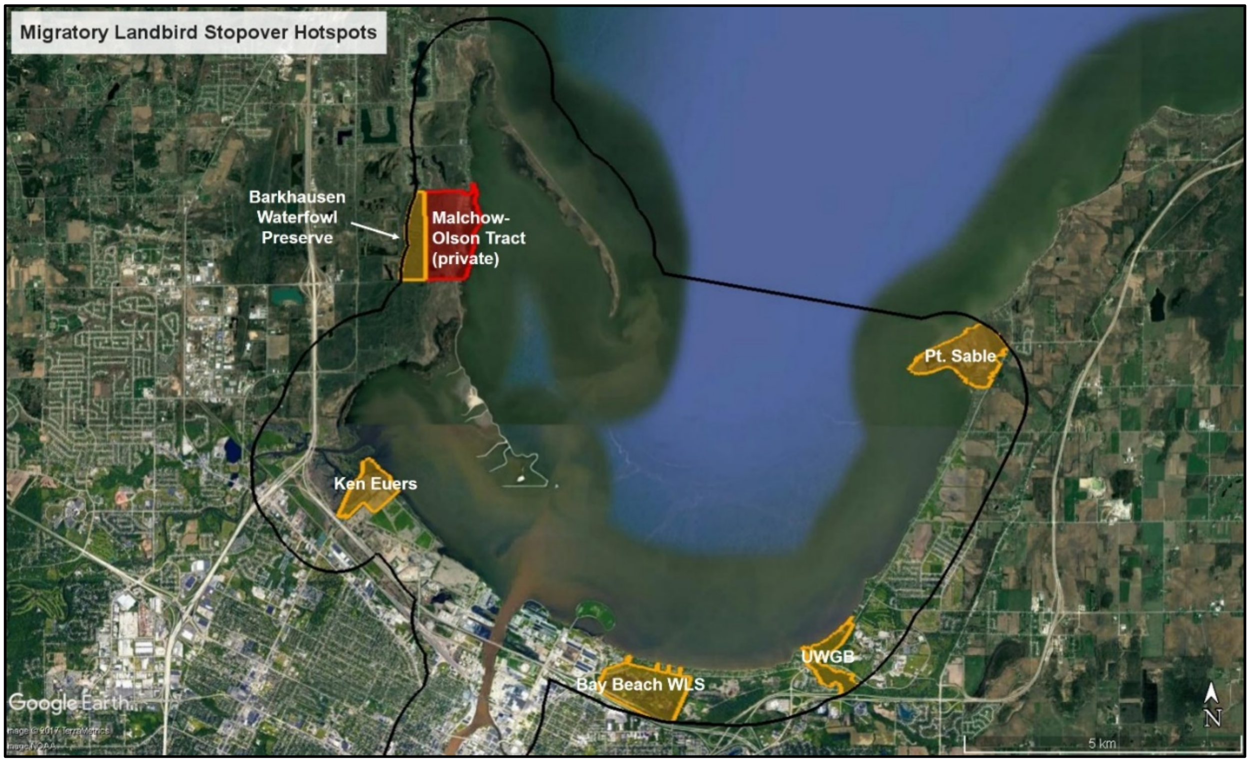


Figure 2.48. Six migratory landbird stopover hotspots within the Lower Green Bay and Fox River Area of Concern based on eBird records (2017), Important Bird Area designations, and our expert opinion. All sites outlined in orange have public access, though the Malchow/Olson Tract (outlined in red) is privately owned and not open to the public. Map was made using Google Earth Pro software.

Based on eBird (2017) records and our observations in the LGB&FR coastal zone over more than three decades, we assign a baseline condition of 7.0 to this group (Figure 2.49). Migratory landbirds currently comprise a diverse and abundant group that is generally doing well in the LGB&FR coastal zone (Table 2.14). In addition to habitat loss through urbanization, woody invasive plants, such as buckthorn (e.g., glossy buckthorn, *Frangula alnus*) and non-native honeysuckles (*Lonicera* × *bella*), have replaced native understory plants in many forest (e.g., hardwood swamp) and shrub carr habitats. Honeysuckle fruits provide food for birds, but the nutritional value of these fruits is poorer than that of native species like *Cornus* spp., *Amelanchier* spp., and *Prunus* spp. (Ewert and Hamas 1995, Smith et al. 2013). Likewise, Oguchi et al. (2017) found that birds in migratory stopover habitats dominated by invasive fruit-bearing shrubs and trees had poorer immune status and lower immunostimulatory antioxidants than conspecifics in habitats dominated by native shrubs and trees. Davis (2011) argued that non-native species pose little or no threat to migratory birds, but this conclusion is based mainly on the quantity rather than the quality of food for migrants.

Planting native shrubs (e.g., cherry [*Prunus* spp.], dogwood [*Cornus* spp.], grape [*Vitis riparia*]) in urban parks and degraded woodlands will increase the availability of quality, nutritional fruits for migrant landbirds, especially during August, September, and October (Drummond 2005). Other steps to improve the condition of migrant landbird populations include 1) encouraging native landscaping in backyards and commercial grounds, 2) conserving hardwood swamps, which provide abundant insects and resting habitat for long-distance migrants, and 3) improving all types of natural habitats in the lower Green Bay coastal zone, especially along shorelines.

Assessment of migratory bird populations is challenging because weather patterns and factors outside the LGB&FR AOC affect numbers of migrants during any given season. For this reason, data from point surveys are not reliable metrics for assessing the status of migratory land birds unless they are conducted during peak migration periods, which can be quite unpredictable. We propose a simpler metric, which is the number of sites of approximately 100 ha (247 acres) where at least one annual "big day" count exceeds 30 species, combined from 6 predominantly migrant bird families (Table 2.14 and Figure 2.49): Tyrannidae (New World flycatchers; 10 likely species), Vireonidae (vireos; 7 likely species), Turdidae (thrushes; 7 likely species), Parulidae (wood warblers; 35 likely species), Emberizidae (New World sparrows; 14 likely species), and Cardinalidae (tanagers, grosbeaks, Indigo Bunting, and Dickcissel; 6 likely species). Altogether, nearly 80 species of birds in these families are regular migrants in the LGB&FR AOC. The "big day" total of 30 species may come from any day during spring migration. Birds are easiest to find and identify during spring, so we propose this season rather than fall. Some species in these families are residents (e.g., American Robin [*Turdus migratorius*], Northern Cardinal [*Cardinalis cardinals*]), but we include all species for the sake of simplicity. The shape of the area may be irregular, including long, linear polygons of approximately 100 ha along the Fox River Trail. "Big day" reports may involve bird clubs, students, and other groups or individuals, providing an opportunity for citizen scientists to contribute meaningfully to the monitoring effort. The raw metric (number of sites) can be converted to a 0-10 scale by referring to a nonlinear conversion curve (Figure 2.49). Big day counts must be completed during a single day, but this day may occur at any time during the spring migration period (April-May), thus accommodating year-to-year variation in the timing of bird migration peaks.

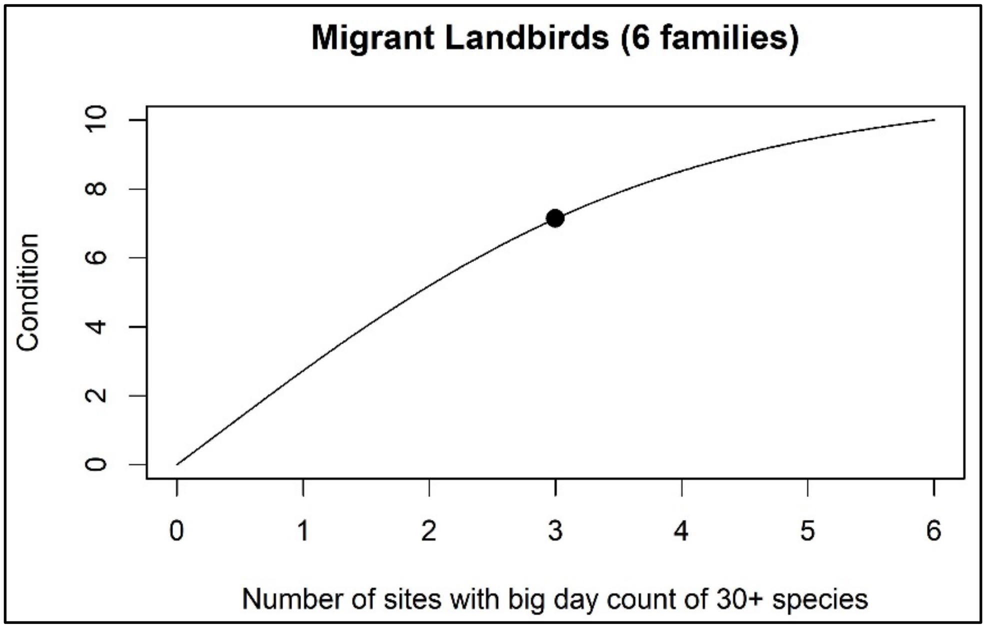
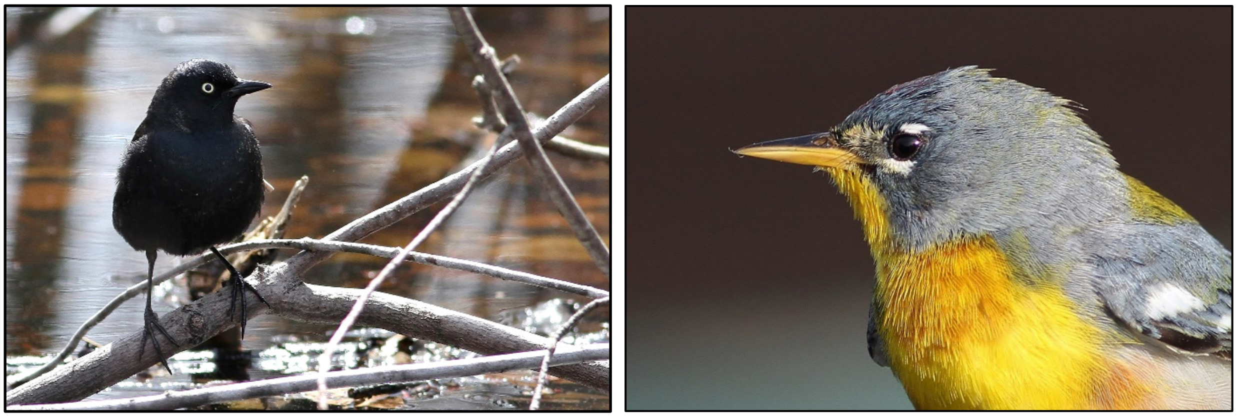


Figure 2.49. Migratory landbirds conversion curve for converting number of sites with "big day" counts of 30 or more target migrant species (x-axis) into a standardized condition score ranging from 0-10 (y-axis).

Table 2.14. Migratory landbird species used to calculate “big day” totals during spring migration at a site of approximately 100 ha (247 acres). Any species from these 6 families can be counted toward the “big day” total.

Common Name	Scientific Name	Order	Family
Olive-sided Flycatcher	*Contopus cooperi*	Passeriformes	Tyrannidae
Eastern Wood-Pewee	*Contopus virens*	Passeriformes	Tyrannidae
Yellow-bellied Flycatcher	*Empidonax flaviventris*	Passeriformes	Tyrannidae
Acadian Flycatcher	*Empidonax virescens*	Passeriformes	Tyrannidae
Alder Flycatcher	*Empidonax alnorum*	Passeriformes	Tyrannidae
Willow Flycatcher	*Empidonax traillii*	Passeriformes	Tyrannidae
Least Flycatcher	*Empidonax minimus*	Passeriformes	Tyrannidae
Eastern Phoebe	*Sayornis phoebe*	Passeriformes	Tyrannidae
Great Crested Flycatcher	*Myiarchus crinitus*	Passeriformes	Tyrannidae
Eastern Kingbird	*Tyrannus tyrannus*	Passeriformes	Tyrannidae
White-eyed Vireo	*Vireo griseus*	Passeriformes	Vireonidae
Bell's Vireo	*Vireo bellii*	Passeriformes	Vireonidae
Yellow-throated Vireo	*Vireo flavifrons*	Passeriformes	Vireonidae
Blue-headed Vireo	*Vireo solitarius*	Passeriformes	Vireonidae
Warbling Vireo	*Vireo gilvus*	Passeriformes	Vireonidae
Philadelphia Vireo	*Vireo philadelphicus*	Passeriformes	Vireonidae
Red-eyed Vireo	*Vireo olivaceus*	Passeriformes	Vireonidae
Eastern Bluebird	*Sialia sialis*	Passeriformes	Turdidae
Veery	*Catharus fuscescens*	Passeriformes	Turdidae
Gray-cheeked Thrush	*Catharus minimus*	Passeriformes	Turdidae
Swainson's Thrush	*Catharus ustulatus*	Passeriformes	Turdidae
Hermit Thrush	*Catharus guttatus*	Passeriformes	Turdidae
Wood Thrush	*Hylocichla mustelina*	Passeriformes	Turdidae
American Robin	*Turdus migratorius*	Passeriformes	Turdidae
Ovenbird	*Seiurus aurocapilla*	Passeriformes	Parulidae
Worm-eating Warbler	*Helmitheros vermivorum*	Passeriformes	Parulidae
Louisiana Waterthrush	*Parkesia motacilla*	Passeriformes	Parulidae
Northern Waterthrush	*Parkesia noveboracensis*	Passeriformes	Parulidae
Golden-winged Warbler	*Vermivora chrysoptera*	Passeriformes	Parulidae
Blue-winged Warbler	*Vermivora cyanoptera*	Passeriformes	Parulidae
Black-and-white Warbler	*Mniotilta varia*	Passeriformes	Parulidae
Prothonotary Warbler	*Protonotaria citrea*	Passeriformes	Parulidae
Tennessee Warbler	*Oreothlypis peregrina*	Passeriformes	Parulidae
Orange-crowned Warbler	*Oreothlypis celata*	Passeriformes	Parulidae
Nashville Warbler	*Oreothlypis ruficapilla*	Passeriformes	Parulidae
Connecticut Warbler	*Oporornis agilis*	Passeriformes	Parulidae
Mourning Warbler	*Geothlypis philadelphia*	Passeriformes	Parulidae
Kentucky Warbler	*Geothlypis formosa*	Passeriformes	Parulidae
Common Yellowthroat	*Geothlypis trichas*	Passeriformes	Parulidae
Hooded Warbler	*Setophaga citrina*	Passeriformes	Parulidae

American Redstart	*Setophaga ruticilla*	Passeriformes	Parulidae
Cape May Warbler	*Setophaga tigrina*	Passeriformes	Parulidae
Cerulean Warbler	*Setophaga cerulea*	Passeriformes	Parulidae
Northern Parula	*Setophaga americana*	Passeriformes	Parulidae
Magnolia Warbler	*Setophaga magnolia*	Passeriformes	Parulidae
Bay-breasted Warbler	*Setophaga castanea*	Passeriformes	Parulidae
Blackburnian Warbler	*Setophaga fusca*	Passeriformes	Parulidae
Yellow Warbler	*Setophaga petechia*	Passeriformes	Parulidae
Chestnut-sided Warbler	*Setophaga pensylvanica*	Passeriformes	Parulidae
Blackpoll Warbler	*Setophaga striata*	Passeriformes	Parulidae
Black-throated Blue Warbler	*Setophaga caerulescens*	Passeriformes	Parulidae
Palm Warbler	*Setophaga palmarum*	Passeriformes	Parulidae
Pine Warbler	*Setophaga pinus*	Passeriformes	Parulidae
Yellow-rumped Warbler	*Setophaga coronata*	Passeriformes	Parulidae
Yellow-throated Warbler	*Setophaga dominica*	Passeriformes	Parulidae
Black-throated Green Warbler	*Setophaga virens*	Passeriformes	Parulidae
Canada Warbler	*Cardellina canadensis*	Passeriformes	Parulidae
Wilson's Warbler	*Cardellina pusilla*	Passeriformes	Parulidae
Yellow-breasted Chat	*Icteria virens*	Passeriformes	Parulidae
Eastern Towhee	*Pipilo erythrophthalmus*	Passeriformes	Emberizidae
Chipping Sparrow	*Spizella passerina*	Passeriformes	Emberizidae
Clay-colored Sparrow	*Spizella pallida*	Passeriformes	Emberizidae
Field Sparrow	*Spizella pusilla*	Passeriformes	Emberizidae
Vesper Sparrow	*Pooecetes gramineus*	Passeriformes	Emberizidae
Savannah Sparrow	*Passerculus sandwichensis*	Passeriformes	Emberizidae
Grasshopper Sparrow	*Ammodramus savannarum*	Passeriformes	Emberizidae
Henslow's Sparrow	*Centronyx henslowii*	Passeriformes	Emberizidae
Fox Sparrow	*Passerella iliaca*	Passeriformes	Emberizidae
Song Sparrow	*Melospiza melodia*	Passeriformes	Emberizidae
Lincoln's Sparrow	*Melospiza lincolnii*	Passeriformes	Emberizidae
Swamp Sparrow	*Melospiza georgiana*	Passeriformes	Emberizidae
White-throated Sparrow	*Zonotrichia albicollis*	Passeriformes	Emberizidae
White-crowned Sparrow	*Zonotrichia leucophrys*	Passeriformes	Emberizidae
Summer Tanager	*Piranga rubra*	Passeriformes	Cardinalidae
Scarlet Tanager	*Piranga olivacea*	Passeriformes	Cardinalidae
Northern Cardinal	*Cardinalis*	Passeriformes	Cardinalidae
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	Passeriformes	Cardinalidae
Indigo Bunting	*Passerina cyanea*	Passeriformes	Cardinalidae
Dickcissel	*Spiza americana*	Passeriformes	Cardinalidae



Migratory landbirds: Rusty Blackbird (left) and Northern Parula (*Setophaga americana*; right). Photographs taken by Scott Giese.

Wooded Wetland Birds (breeding season)

The "wooded wetland birds (breeding)" species group consists of birds that breed in hardwood swamps, which includes forest-dwelling woodpeckers, vireos, flycatchers, cuckoos, nuthatches, thrushes, warblers, and a few other species (Table 2.15), as well as shrub carr-affiliated species (Table 2.16). To identify species that use wooded wetlands or shrub carr for nesting, we compiled lists provided by Fowler and Howe (1987), Hoffman and Mossman (1993), and Hoffman (1989) as well as species accounts provided by the Cornell Lab of Ornithology's Birds of North American Online and the "All About Birds" webpage. These sources were not restricted to lower Green Bay, however, so we excluded some of the listed species that were out of range, typically breed in non-wooded wetland habitats, were non-native (e.g., Ring-necked Pheasant [*Phasianus colchicus*]), or were more closely associated with people (e.g., American Robin [*Turdus migratorius*]). We also identified which hardwood swamp- and shrub carr-affiliated bird species currently nest in the LGB&FR AOC using data provided by the Wisconsin Breeding Bird Atlas 2 Project (eBird 2017; Tables 2.15-2.16). Some species that we have identified as wooded wetland breeders do not necessarily exclusively breed in hardwood swamps or shrub carr. In fact, many species use other habitats (e.g., Blue Jay, Ovenbird).

Nearly 30% of the LGB&FR AOC's natural habitats make up hardwood swamps, which are forested wetlands dominated by some combination of green ash (*Fraxinus pennsylvanica*), red maple (*Acer rubrum*), eastern cottonwood (*Populus deltoides*), and swamp white oak (*Quercus bicolor*). Native woody understory dominants include nannyberry (*Viburnum lentago*), shrubby dogwoods (*Cornus* spp.), and winterberry holly (*Ilex verticillata*), though a considerable amount of these hardwood swamps are dominated by invasive glossy buckthorn (*Frangula alnus*) and honeysuckle species (e.g., *Lonicera* × *bella*). Once the snow melts in the spring, these wet hardwood swamps are often filled with standing water that eventually dry out by early to mid-summer. Within the LGB&FR AOC, relatively large tracts of continuous hardwood swamps are found along the west shore of the bay, particularly at Barkhausen Waterfowl Preserve, Fort Howard Wildlife Area, Malchow/Olson Tract, and Long Tail Beach Road Hardwood Swamp, which undoubtedly have representative and probably species-rich assemblages of breeding birds (Figure 2.50). Along the east shore, a substantial amount of hardwood swamp is present at Bay Beach Wildlife Sanctuary East and West, UW-Green Bay campus, and Point Sable and fragmented patches along the Fox River (Figure 2.50). About 4% of the LGB&FR AOC's natural habitats make up shrub carr habitat, which is a transitional habitat that occurs between emergent marshes and hardwood swamp, that is especially found along the west shore. Dominant native woody plants include willow (*Salix* spp.), red-osier dogwood (*Cornus sericea*), silky dogwood (*C. amomum*), and meadowsweet (*Spiraea alba*), though glossy buckthorn is also prevalent.

Because this species group is rather large and diverse, the needs of each species vary for appropriate nesting and foraging habitats. Flycatchers, such as Eastern Wood-Pewee, need open gaps in the forested wetlands with adequate perches used for catching insects “on the wing,” while birds, such as Wood Thrush, prefer interior forest with little edge (Hoover et al. 1995). Woodpeckers and nuthatches search for food and excavate cavities for nesting in dead trees, rotting wood, hollowed out trees, and snags. Broad-winged Hawks prefer younger forests with openings for breeding (Goodrich et al. 2014), unlike Red-shouldered Hawks, which seek more mature forest stands (Dykstra et al. 2008). Hardwood swamp micro-habitats created by fallen logs, coarse woody debris, and snags are preferential to species like Winter Wren (Hejl et al. 2002). Dense leaf litter along the forest floor is used by Ovenbirds and Veeries both for foraging for insects (e.g., ants) and nest building (Hoover et al. 1995, Porneluzi et al. 2011, Heckscher et al. 2017). All of these features are present in mature hardwood swamps that experience the natural disturbance regime typical of forests in the western Great Lakes.

Historically, little has been published about wooded wetland breeding birds in northeastern Wisconsin. However, the west shore was largely covered by swamp conifer forest (1840s PLSS records from the WDNR Surface Water Data Viewer) with black spruce (*Picea mariana*) and balsam fir (*Abies balsamea*; T. Erdman, *pers. comm.*), so it is likely that birds of northern wet mesic forest habitat were more abundant, diverse, and widespread than they are today in the LGB&FR AOC. During the 1800s and early 1900s, a significant amount of Wisconsin’s forests was heavily logged and have since been converted to farmland, development, and early successional forests dominated by *Populus* spp. and other pioneer tree species (Frelich 1995). The original RAP states the importance of having “a balance of diverse habitat types exist within the AOC that supports all life stage requirements of fish and wildlife populations including multiple wetland types (for example: …forested and shrub…)” (Wisconsin Department of Natural Resources 2016a). The document also stresses the need for having “populations of traditionally harvested wildlife species,” which includes wooded wetland breeder, Ruffed Grouse, and shrub-forest breeder, American Woodcock (Wisconsin Department of Natural Resources 2016a).

According to 2015-2017 data from the Wisconsin Breeding Bird Atlas 2 Project, many important wooded wetland breeding birds currently nest in the LGB&FR AOC, especially at Barkhausen Waterfowl Preserve, Cottage Grove Complex, Point Sable, Bay Beach Wildlife Sanctuary West, and Peters Marsh (Tables 2.15-2.16). Multiple confirmed breeding records have been reported for forest-dwelling species Baltimore Oriole (9), Black-capped Chickadee (8), Gray Catbird (6), Northern Flicker (6), Blue Jay (5), and Downy Woodpecker (5) and shrub carr-affiliated species Cedar Waxwing (6), Yellow Warbler (6), American Goldfinch (5), and Song Sparrow (5; eBird 2017). Presently, no confirmed breeding records have been reported in the LGB&FR AOC for Black-billed Cuckoo, Broad-winged Hawk, Brown Creeper, Mourning Warbler, Northern Waterthrush, Ovenbird, Red-breasted Nuthatch, Red-eyed Vireo, Ruffed Grouse, Scarlet Tanager, Winter Wren, Yellow-billed Cuckoo, and Alder Flycatcher, except for “probable” (e.g., agitated adult, courtship display) or “possible” (e.g., singing male) breeding records (Tables 2.15-2.16; eBird 2017); however, Alder Flycatcher more frequently use alder thickets in northern Wisconsin. Black-and-white Warbler and Red-shouldered Hawk were not reported at all during the breeding season in the LGB&FR AOC, though they do use forested wetlands in this region for breeding. However, two more years are left in the Wisconsin Breeding Bird Atlas 2 Project; undoubtedly additional breeding records will be noted in the future in the LGB&FR AOC.

This species/species group is important because some of these species are predators of aquatic invertebrates and, in some cases, anurans that depend on the coastal or nearshore environment. Avian predators in coastal swamp hardwoods may accumulate environmental contaminants such as pesticides, heavy metals, and polychlorinated biphenyls (PCBs; Qualls et al. 2013), though they are not tied as closely as other priority species and species groups. With the exception of raptors, which may eat small mammals and birds, most wooded wetland birds eat insects (e.g., flies, beetles, dragonflies), other invertebrates (e.g., spiders, worms), fruits, and seeds.

Based on eBird (2017) records and our expert opinion, we assign a baseline condition of 6.0 to this group since it is currently diverse and somewhat abundant regionally. Several individual species in this group, however, might not be secure as breeders in forests or shrub carr of the LGB&FR AOC (e.g., Brown Creeper, cuckoos, Ovenbird, Willow Flycatcher; Tables 2.15-2.16). Understories of many of these hardwood swamps, however, are dominated by aggressive, invasive plant species such as glossy buckthorn and honeysuckle. These invasive shrubs provide inferior nutrition compared to the native species that they replace (Drummond 2005, Ewert and Hamas 1995), and fruits of invasive shrubs may cause diarrhea (Sherburne 1972). Restoring these forest understories (and shrub carr) with native shrubs, such as cherry (*Prunus* spp.), *Viburnum* spp., and dogwoods (*Cornus* spp.), will improve these habitats and ultimately support higher numbers of the birds that use these native plants for nesting. Non-native earthworms (*Lumbricus* spp.) and slugs have also invaded hardwood forests of the LGB&FR AOC, bringing with them additional negative effects on breeding birds such as Ovenbird (Loss et al. 2012).

A cost effective method for assessing wooded wetland breeding birds is to conduct an array of standard 10-minute unlimited-distance point counts (Knutson et al. 2008), from which a robust index of ecological condition (IEC) can be calculated based on known responses of Wisconsin breeding birds to disturbance (Gnass Giese et al. 2015). Species response curves can be improved further and regionalized as a result of thousands of point counts completed during the Wisconsin Breeding Bird Atlas 2 Project. The IEC is inherently scaled from 0-10, so calibration with our preliminary estimate of condition (6.0) will be simple (Figure 2.51). Since the location of target areas might change depending on restoration efforts and disturbance, we suggest a geographically-flexible metric comprised of the average of the 10 highest IEC scores from independent points (separated by at least 1 km) within the LGB&FR AOC nearshore boundary (i.e., within 1 km of the LGB&FR AOC shoreline). Sampling might include many more than 10 points, but only the 10 highest scores will contribute to the metric.

Management actions and projects that will improve the condition of wooded wetland breeding birds include: 1) maintaining coarse woody debris and natural disturbances in wooded wetlands, 2) removing buckthorn, honeysuckles, and other invasive understory species from priority hardwood swamps and shrub carr in the LGB&FR AOC, and 3) formally protecting large tracts of remnant hardwood swamps and shrub carr in the coastal zone through conservation easements, designations of sensitive area, or other mechanisms.

Table 2.15. Forest-dwelling wooded wetland breeding birds that have been confirmed (“C”) as breeding or are suspected to breed (“Pr” = “probable” [e.g., agitated adult, copulation]; “Po” = “possible” [e.g., singing]) in the Lower Green Bay and Fox River Area of Concern (2015-2017) listed by priority area / site based on the Wisconsin Breeding Bird Atlas 2 (eBird 2017). Wooded wetland breeders, Red-shouldered Hawk (*Buteo lineatus*) and Black-and-white Warbler (*Mniotilta varia*), are not currently breeding in this area but should be.

Species	Barkhausen Waterfowl Preserve	Bay Beach West	Cottage Grove Complex	Duck Creek Area	Fort Howard Wildlife Area	Fox River	Ken Euers	Long Tail Beach Rd. Hardwood Swamp	Point Sable	UWGB
American Crow[1]	C	Pr	Pr			C	Po		C	C
American Redstart[2]	C	Pr	C		C	Po			Pr	C
Baltimore Oriole[3]	C	C	C		C	C	C	C	C	C
Black-billed Cuckoo[4]				Po					Pr	Po
Black-capped Chickadee[5]	C	C	C		C	C	C		C	C
Blue Jay[6]	C	C	Pr			C			C	C
Broad-winged Hawk[7]					Po					
Brown Creeper[8]									Pr	
Downy Woodpecker[9]	C	C	Po		C	Pr	Pr		C	C
Eastern Wood-Pewee[10]	Pr	Po	Pr		Pr				Pr	Po
Gray Catbird[11]	C	C	Pr		Po	C	C		C	C
Great Crested Flycatcher[12]	C	C	C		Pr	Pr		Po	C	Po
Great Horned Owl[13]		C	Pr						C	
Hairy Woodpecker[14]		C	C		Po	Po		C	C	Po
Least Flycatcher[15]	Po		Pr		C	Po				Pr
Mourning Warbler[16]	Pr								Po	
Northern Flicker[17]	C	C	C	C		Po	Po	Po	C	C
Northern Waterthrush[18]	Po									
Ovenbird[19]	Po		Pr		Pr					
Pileated Woodpecker[20]			Pr		Po			Po	Po	C
Red-bellied Woodpecker[21]	C	C	Pr		Po	Po		Po	C	C
Red-breasted Nuthatch[22]	Po								Po	Po
Red-eyed Vireo[23]	Pr	Pr	Pr		Pr	Pr			Pr	Pr
Rose-breasted Grosbeak[24]	Pr	C	C		C	Po		Po	C	
Ruffed Grouse[25]	Pr									
Scarlet Tanager[26]					Po			Po		
Veery[27]	C		Pr		Pr			Po		
White-breasted Nuthatch[28]	Pr	C	C		Po	Po			C	C
Winter Wren[29]					Pr					
Wood Thrush[30]	Pr	C	Pr		Po				Po	
Yellow-billed Cuckoo[31]	Po							Po		
Yellow-throated Vireo[32]	Po		Pr		C					

Scientific Names: [1] *Corvus brachyrhynchos*, [2] *Setophaga ruticilla*, [3] *Icterus galbula*, [4] *Coccyzus erythropthalmus*, [5] *Poecile atricapillus*, [6] *Cyanocitta cristata*, [7] *Buteo platypterus*, [8] *Certhia americana*, [9] *Picoides pubescens*, [10] *Contopus virens*, [11] *Dumetella carolinensis*, [12] *Myiarchus crinitus*, [13] *Bubo virginianus*, [14] *Picoides villosus*, [15] *Empidonax minimus*, [16] *Geothlypis philadelphia*, [17] *Colaptes auratus*, [18] *Parkesia noveboracensis*, [19] *Seiurus aurocapilla*, [20] *Dryocopus pileatus*, [21] *Melanerpes carolinus*, [22] *Sitta canadensis*,

[23] *Vireo olivaceus*, [24] *Pheucticus ludovicianus*, [25] *Bonasa umbellus*, [26] *Piranga olivacea*, [27] *Catharus fuscescens*, [28] *Sitta carolinensis*, [29] *Troglodytes hiemalis*, [30] *Hylocichla mustelina*, [31] *Coccyzus americanus*, and [32] *Vireo flavifrons*.

Table 2.16. Shrub carr-affiliated wooded wetland breeding birds that have been confirmed ("C") as breeding or are suspected to breed ("Pr" = "probable" [e.g., agitated adult, copulation, courtship display]; "Po" = "possible" [e.g., singing]) in the Lower Green Bay and Fox River Area of Concern (2015-2017) listed by priority area / site based on the Wisconsin Breeding Bird Atlas 2 (eBird 2017).

Species	Barkhausen Waterfowl Preserve	Bay Beach West	Cat Island	Cottage Grove Complex	Duck Creek Area	Fort Howard Wildlife Area	Fox River	Peters Marsh	Point Sable	UWGB
Alder Flycatcher[1]				Po			Po			
American Goldfinch[2]	Pr	Pr		Pr	C		C	C	C	C
American Woodcock[3]		Pr			Pr			Pr	Pr	Pr
Cedar Waxwing[4]	C	C		C		Po	C	C	Po	C
Common Yellowthroat[5]	Pr	Pr	Pr	Pr		Po	Po	C	C	Pr
Song Sparrow[6]	C	Pr	Pr	Po		C	Pr	C	C	C
Willow Flycatcher[7]	Pr				Pr			C	C	
Yellow Warbler[8]	Pr	C	Pr	C	C		Pr	C	C	C

Scientific Names: [1] *Empidonax alnorum*, [2] *Spinus tristis*, [3] *Scolopax minor*, [4] *Bombycilla cedrorum*, [5] *Geothlypis trichas*, [6] *Melospiza melodia*, [7] *Empidonax traillii*, and [8] *Setophaga petechial*.

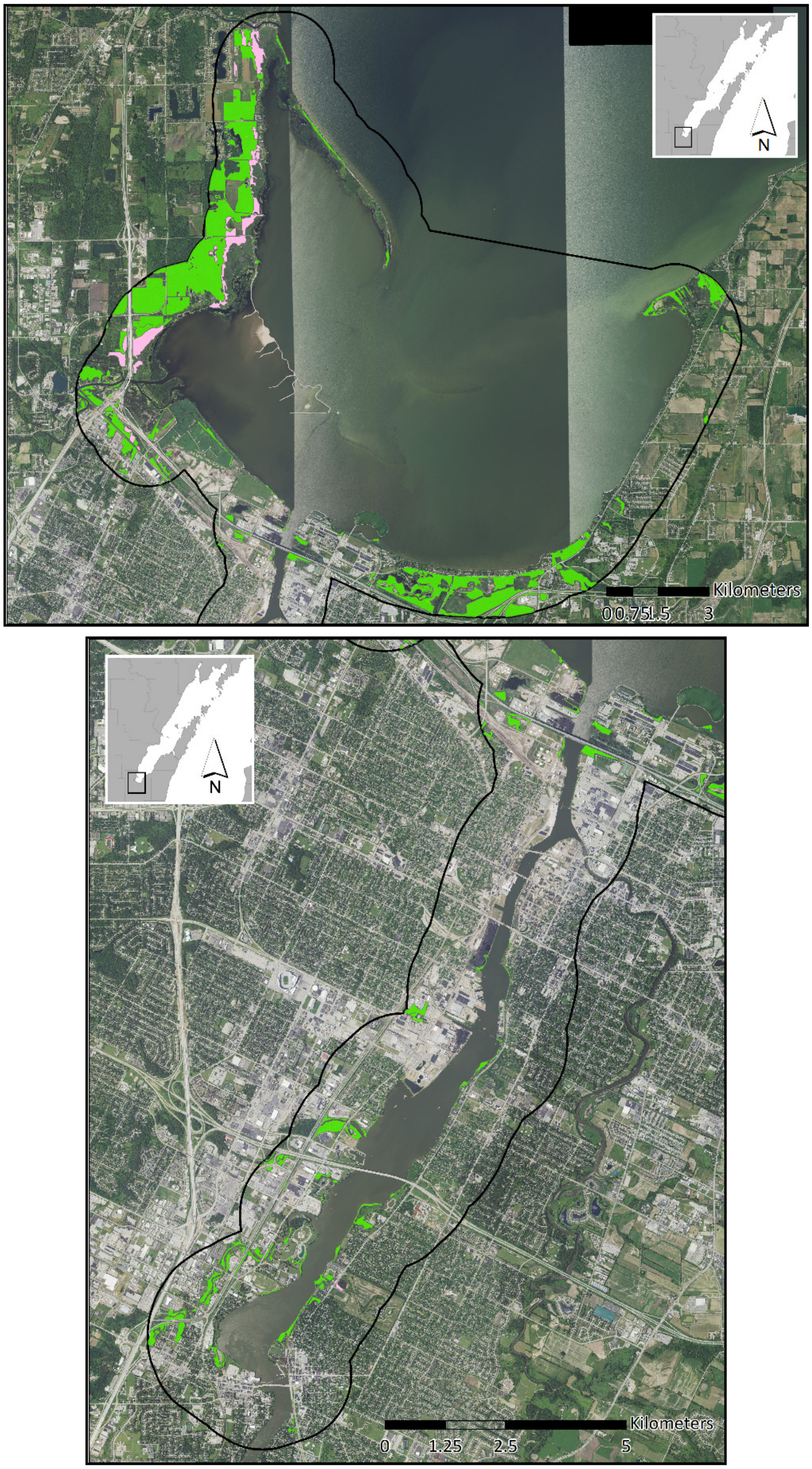


Figure 2.50. Hardwood swamp (green) and shrub carr (pink) habitat in the Lower Green Bay and Fox River Area of Concern. The black line shows the extent of the project study area. Basemap air photo from Brown County (2015). Map was created using ArcGIS 10.5 software (Environmental Systems Research Institute 2016).

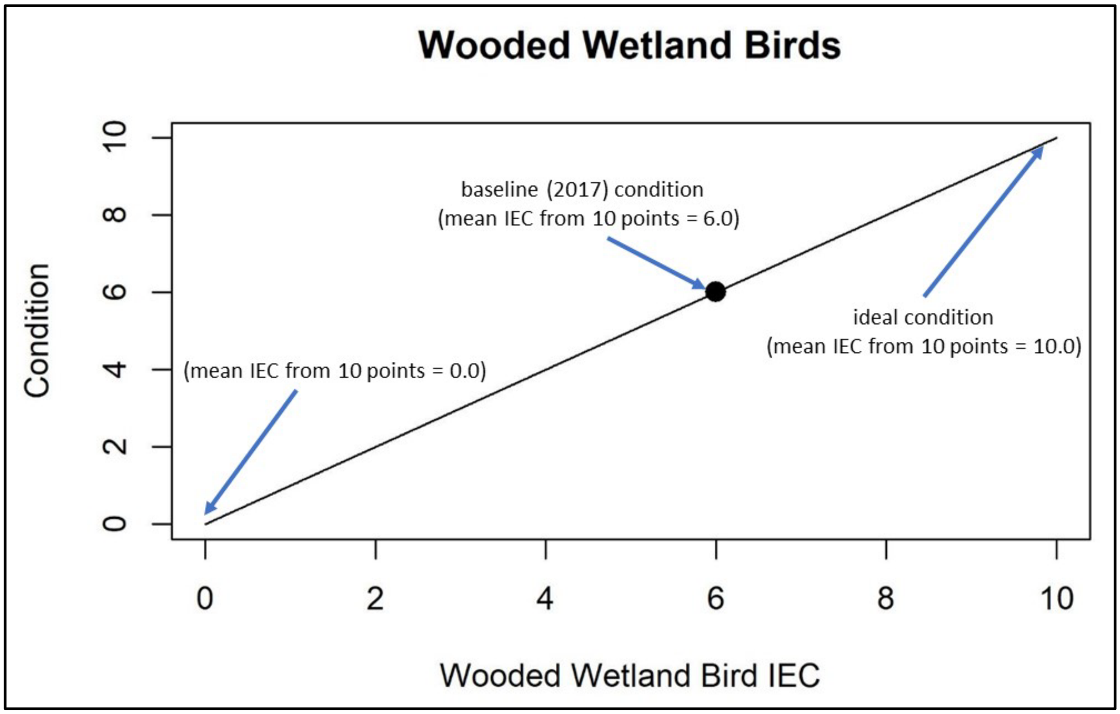


Figure 2.51. Wooded wetland breeding bird assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the wooded wetland bird IEC metric (scaled from 0 [no birds] to 10 [abundant birds]), which is determined through field surveys, and the y-axis is the converted condition for a given wooded wetland bird metric score, which ranges from poor condition (0) to good/ideal condition (10).

Wooded wetland breeding birds: Broad-winged Hawk nest (left; taken by Stephanie Beilke) and Scarlet Tanager (right; taken by Scott Giese).

Fish and Wildlife Habitat

Historical Fish and Wildlife Habitat

In the early 1630s, Frenchman Jean Nicolet first arrived in lower Green Bay when it was primarily inhabited by Native American tribes (Jean Nicolet: French Explorer by the Editors of Encyclopaedia Britannica: https://www.britannica.com/biography/Jean-Nicolet). Lower Green Bay consisted of large beds of wild rice (*Zizania* sp.) and wild celery (*Vallisneria americana*), extensive emergent marsh (*Schoenoplectus* sp., cattail), sedge meadows (*Calamagrostis canadensis*), shrub carr (e.g., *Cornus* spp., *Salix* spp.), swamps, and wet conifer forest (black spruce [*Picea mariana*], balsam fir [*Abies balsamea*]), particularly along the west shore, Duck Creek, and Point Sable (1843 and 1845 maps from La Baye website: http://www.labaye.org/item/30/200, Arthur C. Neville's Map of Historic Sites on Green Bay 1669-1689 [Green Bay Historical Bulletin, 1926, May-June Vol 1 and 2, page 3], personal communication with Thomas Erdman, WDNR Surface Water Data Viewer; Figures 2.52A and 2.53B, Appendix 10.1). Although coastal marshes and meadows dominated lower Green Bay and were subjected to dynamic water level changes, upland forests dominated by oaks (*Quercus* spp.) were common along the bay's and Fox River eastern shores, while sugar maple (*Acer saccharum*) and basswood (*Tilia americana*) forests were common along the western shores of the bay and Fox River (Dorney 1975, WDNR Surface Water Data Viewer; Figure 2.53A, Appendix 10.1). It is relatively well known that wild rice grew in the Duck Creek Delta; however, it is less well known that wild rice grew near the mouth of a small tributary off the Malchow/Olson Tract, which UW-Green Bay's Ellie Roark discovered when geotagging the 1840s PLSS surveyor notes in the LGB&FR AOC (Appendix 10.1).

Historically, there were three large barrier islands (called the Cat Island Chain) that provided critical fish and wildlife habitat for birds, fish, invertebrates, and mammals as well as refugia of native plants and extensive Great Lakes beach (1845 Map of Head of Green Bay, Brown County's online GIS portal's 1938 air photo; Figure 2.53). These islands also protected a massive emergent and submergent marsh complex in the Duck Creek Delta (>200 ha) and present-day Peters Marsh (Brown County 1938 air photo). The true size and extent of the marsh complex that the Cat Island Chain protected can best be appreciated by looking at 1938 and 1960 air photos (provided by Brown County's online GIS portal). According to the 1945 Bordner Surveys, alder, willow, and dogwood occurred along the west shore, Long Tail Point, mouth of Duck Creek, Point Sable, and present-day Bay Beach Wildlife Sanctuary (Figure 2.53). Inland areas along the west shore became croplands and pastures, and much of the east shore's former oak forests were also converted to agricultural lands (Figures 2.52-2.53). Housing development formed in downtown Green Bay (Figure 2.53). Stretches along the Fox River, particularly north of the present-day De Pere Dam, however, still contained emergent marshes, which were reported by the 1945 Bordner Survey and Brown County's 1938 air photos (Figure 2.53).

Due to extremely high water levels in the bay, massive storms, and recently hardened shorelines (e.g., development), the Cat Island Chain of barrier islands largely washed away during the spring of 1973 with the exception of a few small sandy islands, including Cat and Lone Tree Islands (Frieswyk and Zedler 2007). The huge emergent and submergent marshes of the Duck Creek Delta complex also vanished because the islands no longer provided protection and due to high sediment loads further upstream (Frieswyk and Zedler 2007). These significant changes can be viewed on Brown County's 1978 aerial imagery of lower Green Bay.

With some exceptions, information provided by Dorney (1975), Howlett (1974), 1840s PLSS records from the WDNR Surface Water Data Viewer and Roark's work geotagging surveyor notes (Appendix 7.1), historical paper maps from the 1840s, Brown County's 1938, 1960, and 1978 air photos, and other sources report relatively consistent historical plant community descriptions as summarized here. Additional historical vegetation descriptions are available for 12 priority areas within the LGB&FR AOC in Appendix 10.

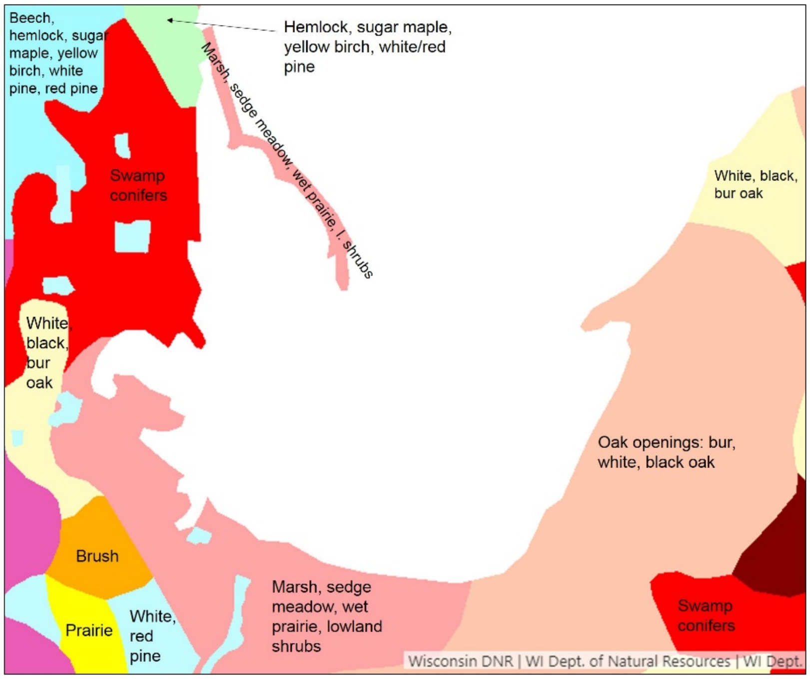


Figure 2.52A. Land cover map based on the original, historical vegetation from the Public Land Survey System based on the 1840s of lower Green Bay. Except for the text labels, this map was produced using the Wisconsin Department of Natural Resources' Surface Water Data Viewer on 29 December 2017: https://dnrmaps.wi.gov/H5/?Viewer=SWDV.

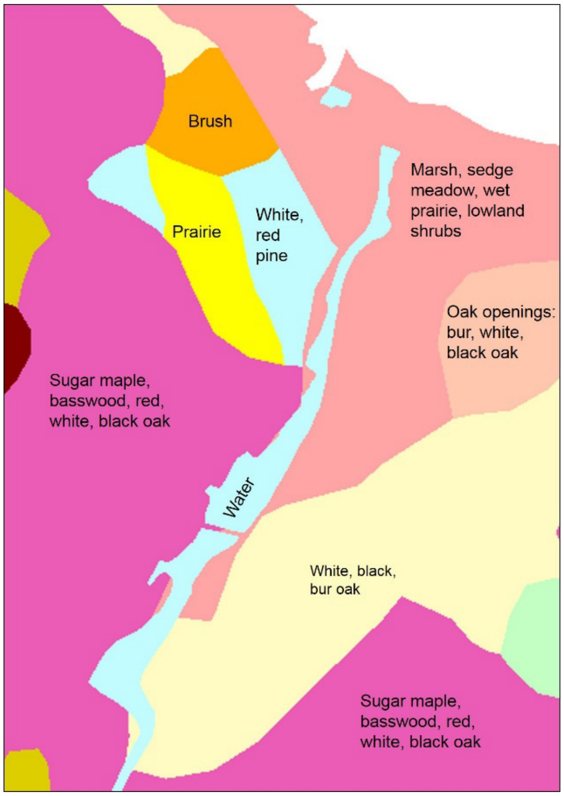
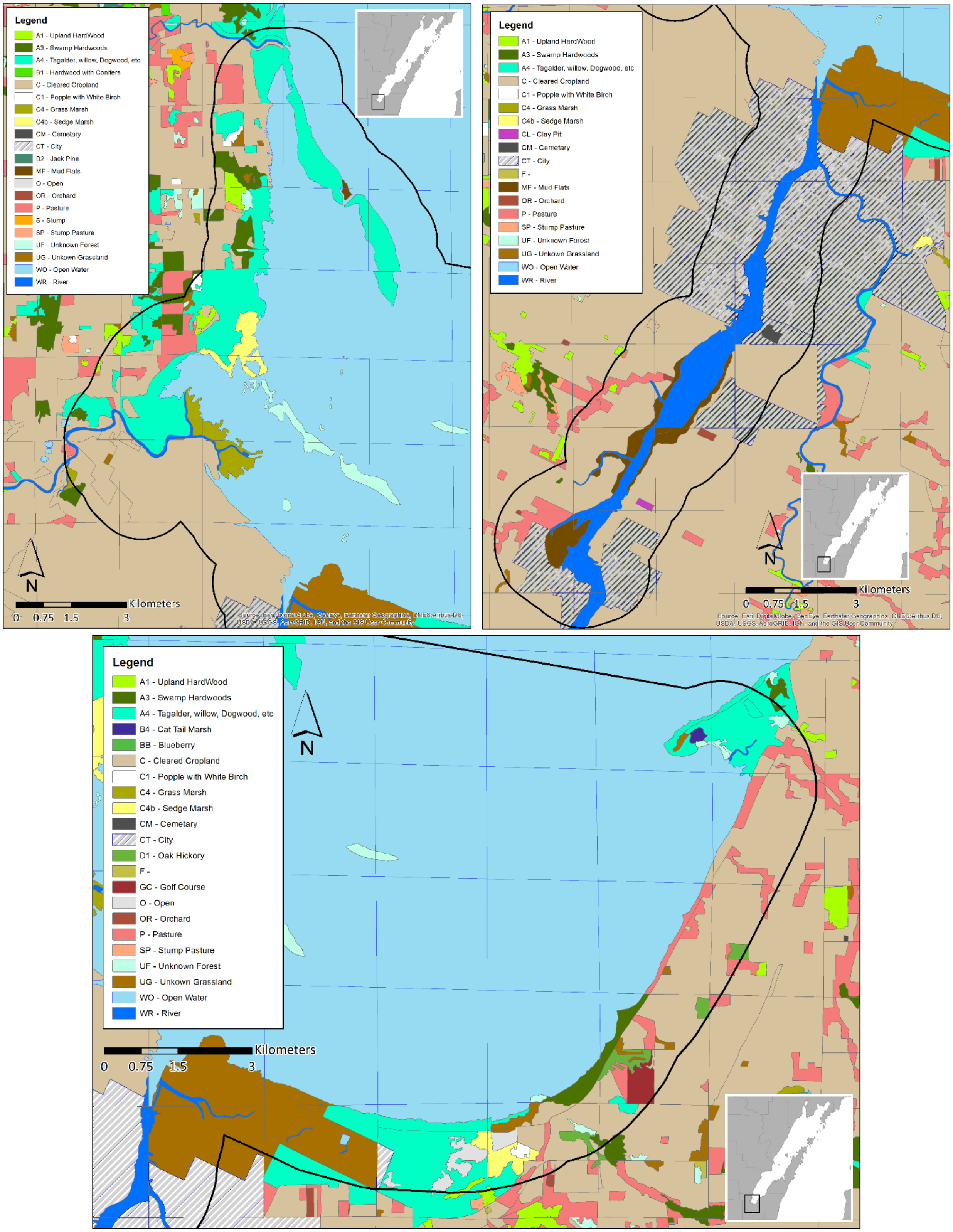


Figure 2.52B. Land cover map based on the original, historical vegetation from the Public Land Survey System based on the 1840s of the lower Fox River. Except for the text labels, this map was produced using the Wisconsin Department of Natural Resources' Surface Water Data Viewer on 29 December 2017: https://dnrmaps.wi.gov/H5/?Viewer=SWDV.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 2.53. Land cover maps based on the 1945 Bordner Survey in Brown County along the west shore (upper left), Fox River (upper right), and east shore (bottom) within 1 km of the Lower Green Bay and Fox River Area of Concern (black line). Bordner land cover geospatial data were produced by the Coastal Bordner Project (Mladenoff et al. 2017). Maps were made using ArcGIS 10.5 software (Environmental Systems Research Institute 2016).

Current Fish and Wildlife Habitat

The total area within the LGB&FR AOC, including the 1 km coastal zone, is approximately 12,800 ha (31,630 acres), 54% of which is open surface water. Of the 5,881 ha of land and wetlands within 1 km of the LGB&FR AOC shoreline, we classified 200 ha as “agricultural” and approximately 3,460 ha as “developed,” including residential neighborhoods, roads, golf courses, mowed lawns, and industrial properties (Figures 2.54-2.56). This leaves 2,481 ha (6,131 acres) or 42% of the land/wetland area as relatively undeveloped, semi-natural land that qualifies as wildlife habitat or potential wildlife habitat, capable of being categorized by the modified WDNR's natural community definitions. Some areas of developed lands, such as abandoned commercial or residential sites, landfills, and industrial waste areas, eventually may be converted into viable wildlife habitat, but these areas are not currently included. Other than open water in Green Bay and the Fox River, the most extensive fish and wildlife habitats in the LGB&FR AOC study area were hardwood swamp (764 ha), high energy emergent marsh (348 ha), submergent marsh/submerged aquatic vegetation (249 ha), and inland emergent marsh (170 ha). Early successional forest and woodland (i.e., other forest; 174 ha), surrogate grasslands, including old fields and other uncultivated grasslands (140 ha), were the only other habitat categories that were represented by >100 ha. Increasing the area of habitat in high priority categories is limited by geographic constraints. Agricultural land in the study area is not extensive, and most of the developed land is irreversibly modified. Improvements in the condition of fish and wildlife habitats, therefore, will be mainly through increases in quality rather than quantity or extent. Changes in the area of individual habitats, such as emergent marsh and submergent marsh, will fluctuate with changes in Green Bay water levels, but the total area of potential fish and wildlife habitat is unlikely to increase significantly in the LGB&FR AOC.

Two imperiled habitats, undeveloped Great Lakes beach and southern sedge meadow, were once widespread in the LGB&FR AOC but today are represented by only small remnants. Air photos from 1938 show extensive areas of coastal meadows that likely were dominated by tussock sedge (*Carex stricta*) and Canada bluejoint grass (*Calamagrostis canadensis*). In addition to areas that have been supplanted by urban or industrial development, *Carex*/*Calamagrostis* meadows today have been replaced by mosaics of weedy forbs and non-native grasses (including reed canary grass [*Phalaris arundinacea*] and common reed) or nearly monotypic stands of hybrid cattail.

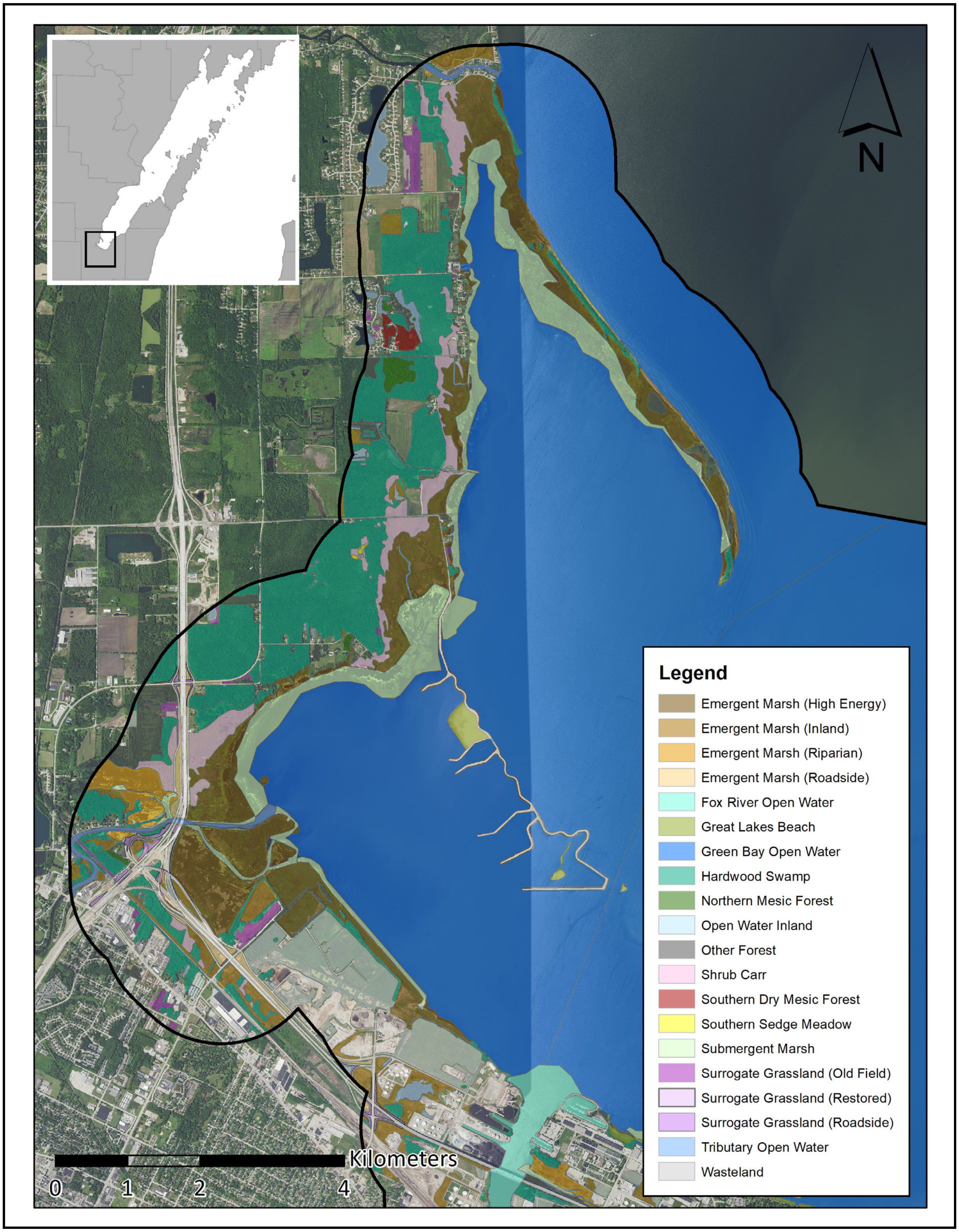


Figure 2.54. Plant communities along the west shore of the Lower Green Bay and Fox River Area of Concern. The black line shows the extent of the project study area. Wasteland (gray) is a plant community type added to distinguish highly disturbed industrial lands that are dominated by exotic grasses and forbs (including invasive *Phragmites australis*) from other types like “surrogate grassland.” Basemap air photo from Brown County (2015). Map was created using ArcGIS 10.5 software (Environmental Systems Research Institute 2016).

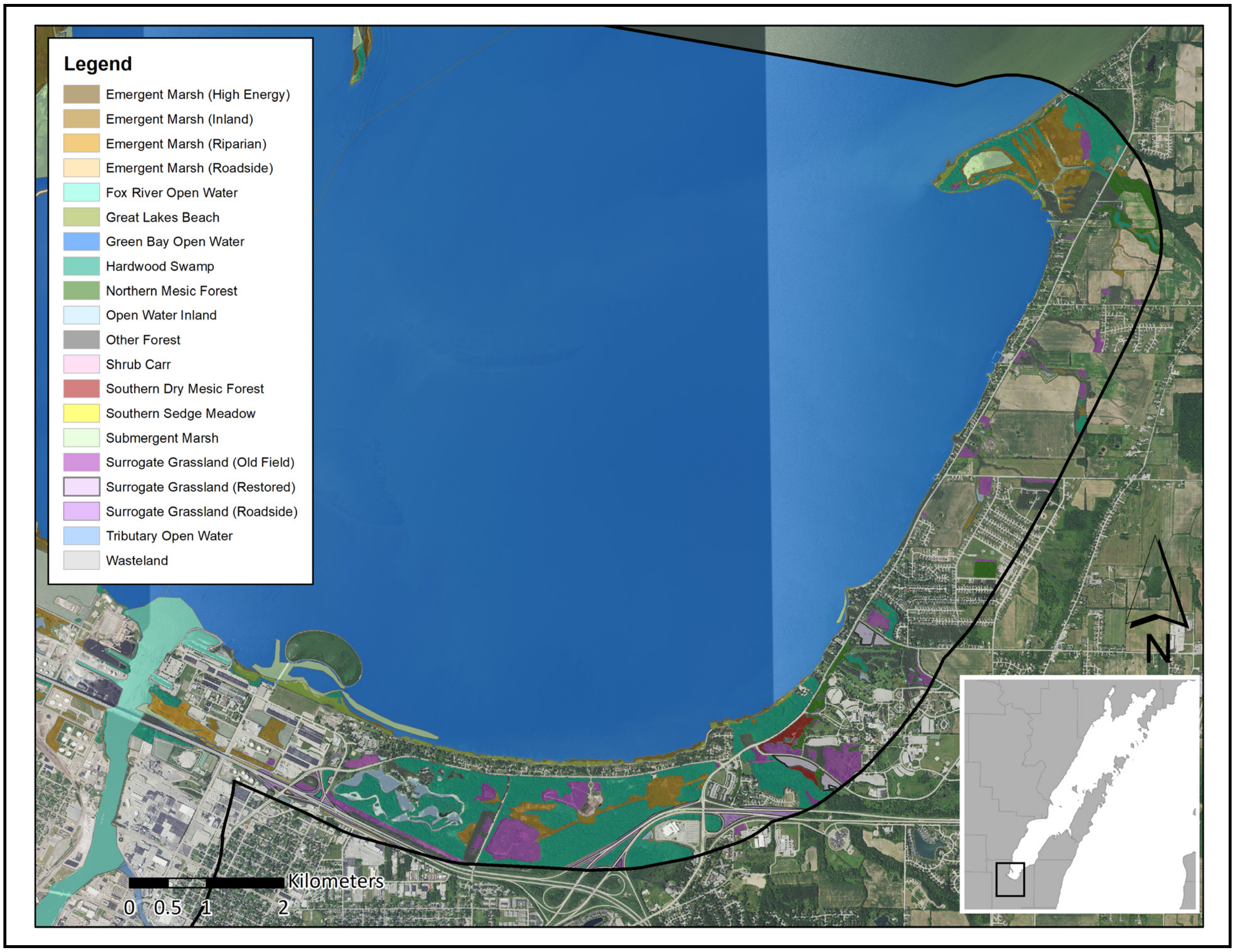


Figure 2.55. Plant communities along the east shore of the Lower Green Bay and Fox River Area of Concern. The black line shows the extent of the project study area. Wasteland (gray) is a plant community type added to distinguish highly disturbed industrial lands that are dominated by exotic grasses and forbs (including invasive *Phragmites australis*) from other types like “surrogate grassland.” Basemap air photo from Brown County (2015). Map was created using ArcGIS 10.5 software (Environmental Systems Research Institute 2016).

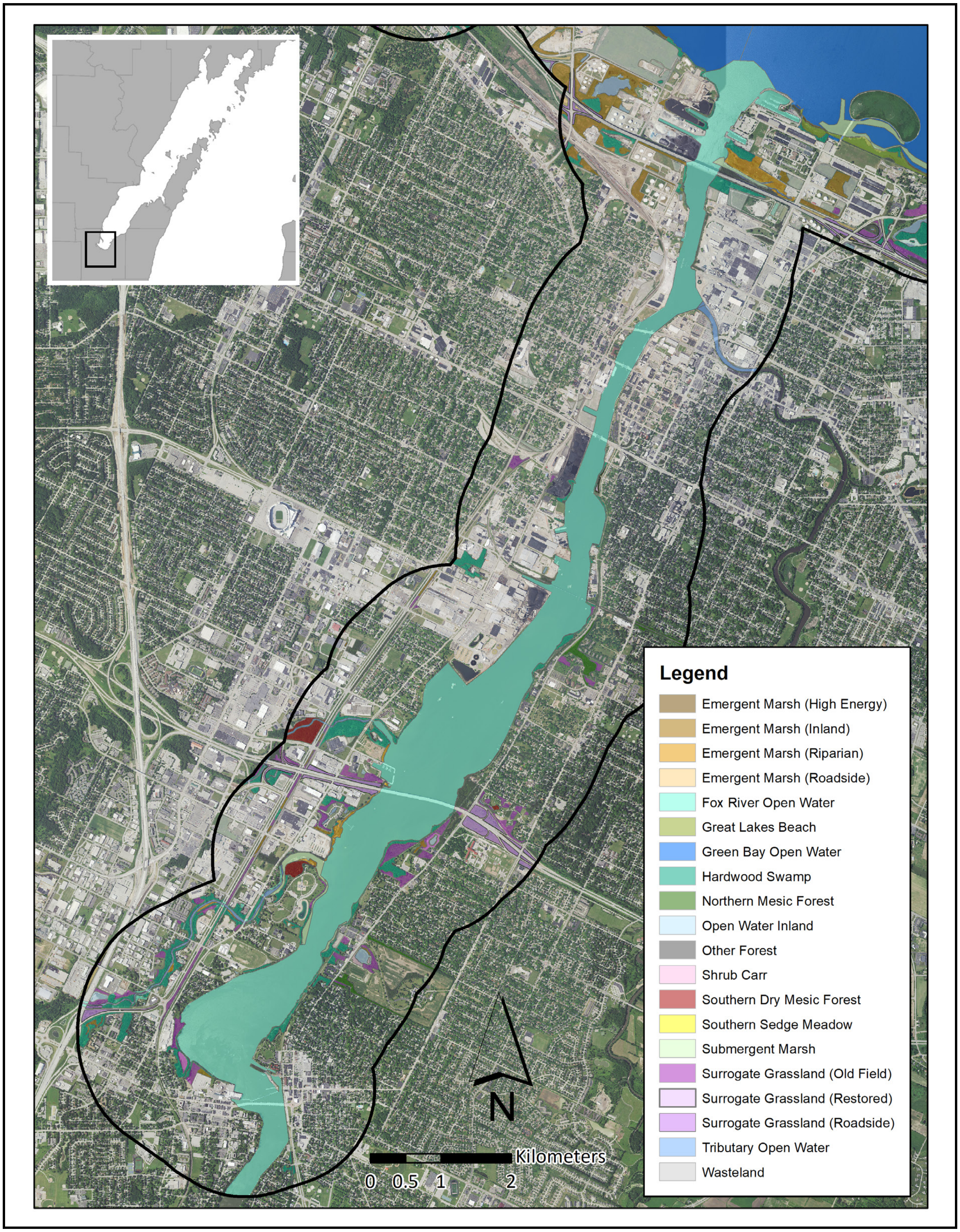


Figure 2.56. Plant communities along the Fox River of the Lower Green Bay and Fox River Area of Concern. The black line shows the extent of the project study area. Wasteland (gray) is a plant community type added to distinguish highly disturbed industrial lands that are dominated by exotic grasses and forbs (including invasive *Phragmites australis*) from other types like “surrogate grassland.” Basemap air photo from Brown County (2015). Map was created using ArcGIS 10.5 software (Environmental Systems Research Institute 2016).

Great Lakes Beach

Great Lakes beach community is found along the coast of Lake Michigan and accounts for just over 1% of land area in the AOC (Figures 2.57-2.58), a small fraction of the undeveloped beach habitat that once occurred here. Great Lakes beach habitats are usually sparsely vegetated due to the strong influence of fluctuating water levels and erosion from breaking waves. However, the upper beach zone, which is typically affected by wind-blown sand and wave spray, supports a unique assemblage of native herbaceous plants. Characteristic dominants of this community in the AOC include American sea-rocket (*Cakile edentula* subsp. *edentula* var. *lacustris*), Canada wild-rye (*Elymus canadensis*), smooth goldenrod (*Solidago gigantea*), beach pea (*Lathyrus japonicus* var. *maritimus*), and common cocklebur (*Xanthium strumarium*, dubiously native). American red raspberry (*Rubus idaeus* subsp. *strigosus*) is sometimes present at the inland periphery of beach zone. These species may be accompanied by a diversity of non-native, eudicot forb species. Seaside spurge (*Euphorbia polygonifolia*), a matted annual forb that is of conservation concern in Wisconsin, is tenuously present at one locality.

Great Lakes beach also offers a critical habitat for foraging, resting, and breeding areas for shorebirds and other animals. Since 2016, the federally endangered Piping Plover (*Charadrius melodus*) has successfully nested in sandy beach habitat within the LGB&FR AOC at the Cat Island Chain Restoration Site. Turtles also use sandy beach areas for nesting and basking, although little information is available about their use of beaches in this AOC. The hairy-necked tiger beetle (*Cicindela hirticollis rhodensis*), a state endangered species, was found on Cat Island beach habitat during the summer of 2017 by Jay Watson. We expect that this species might also be found on other beaches (e.g., Longtail Point) within the AOC. Other rare or uncommon beach invertebrates also likely are present or are potential colonists of remnant beach habitat in the LGB&FR AOC.

Unconsolidated beach habitat was specifically listed as a target for restoration by the original LGB&FR AOC RAP (WDNR 2016), primarily because of the importance of this habitat type for fish and wildlife populations, especially shorebird populations. Lane et al. (1996) noted that the majority of Great Lakes fish species spawn in shallow water, typically on gravel or sand substrates, so maintaining quality beach habitat helps maintain the integrity of important aquatic habitats as well as the land-water interface itself. Reid and Mandrak (2008) likewise described negative effects of beach development on shoreline fish assemblages in northern Lake Erie.

Great Lakes beach is one of two habitat types with the highest priority weight based on historical importance, conservation status within the LGB&FR AOC (State Rank: S2; Global Rank: G3), geographic significance (connection to the bay) and significance this AOC's biodiversity. Great Lakes beach habitat was once widespread in the LGB&FR AOC but today is represented by only small remnants. Undeveloped Great Lakes beach habitat occurs along the shoreline within the LGB&FR AOC at Point au Sable, University of Wisconsin-Green Bay campus, Bay Beach Amusement Park Shoreline, Cat Island Chain Restoration Site, and Longtail Point. Some of these beaches are used extensively for recreation, but we estimate that up to 8 km of quality undeveloped beach can be restored and maintained in the LGB&FR AOC, a realistic ideal condition for our assessment metric (Figure 2.59). We recommend a simple linear measure of undeveloped beach habitat, weighted by quality on a scale from 0 to 1. Converted to our standard scale, 8 km of high-quality beach habitat (quality = 1) would yield a maximum condition score of 10.

Based mainly on our field surveys, the overall condition score for Great Lakes beach habitat is low (=2). Most of the remaining beach habitat in the LGB&FR AOC is in poor condition, being highly invaded by *Phragmites* or other non-native plants, and in many areas naturally occurring sand is covered in zebra and quagga mussel shells. Since much of the remaining Great Lakes beach habitat is publicly owned, however, the possibility of restoration is high. Privately owned beach sections along Point au Sable would benefit from a conservation easement agreement. Limiting access to beaches during peak migration periods for shorebirds and if present, during Piping Plover breeding is important. Beaches are used extensively by migratory birds and bats based on our field research. The diversity and abundance of beach invertebrates in lower Green Bay is poorly known and deserves future study, especially for rare species like the hairy-necked tiger beetle. Other conservation actions to improve the condition of Great Lakes beaches in the LGB&FR AOC include providing shoreline deadwood for turtle basking and fish habitat, removing accumulations of dreissenid mussel shells, controlling invasive species in the nearshore zone, and maintaining native plant communities in adjacent floodplain or upland buffers.

For more information on this habitat visit the WDNR's Great Lakes Beach webpage: http://dnr.wi.gov/topic/EndangeredResources/Communities.asp?mode=detail&Code=CTGEO092WI.

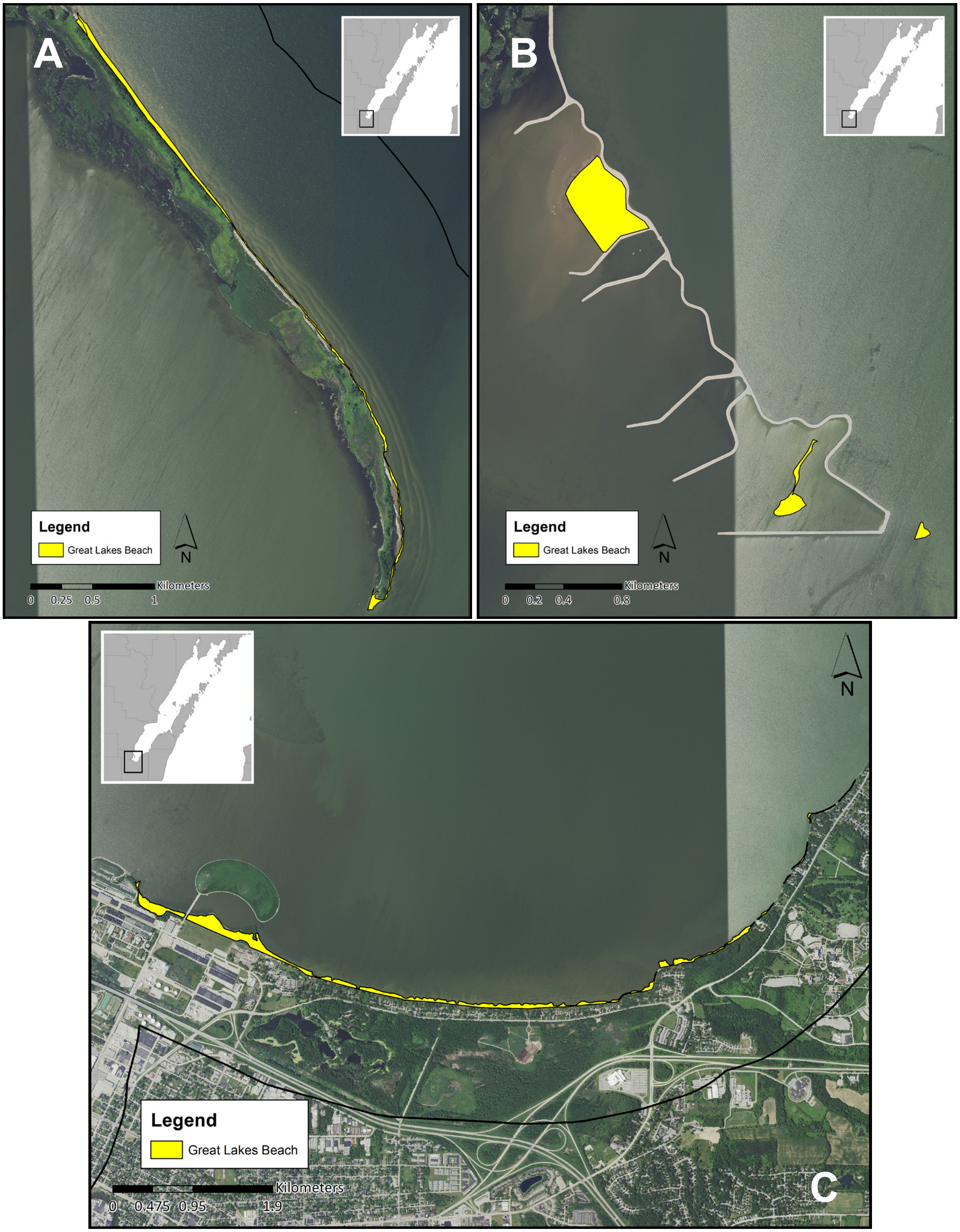


Figure 2.57. Great Lakes beach habitat in the Lower Green Bay and Fox River Area of Concern: A) Longtail Point, B) Cat Island Chain Restoration Site, and C) Bay Beach Amusement Park and the southeastern shoreline of the lower bay. The black line shows the extent of the project study area. Basemap air photo from Brown County (2015). Maps were created using ArcGIS 10.5 software (Environmental Systems Research Institute 2016).

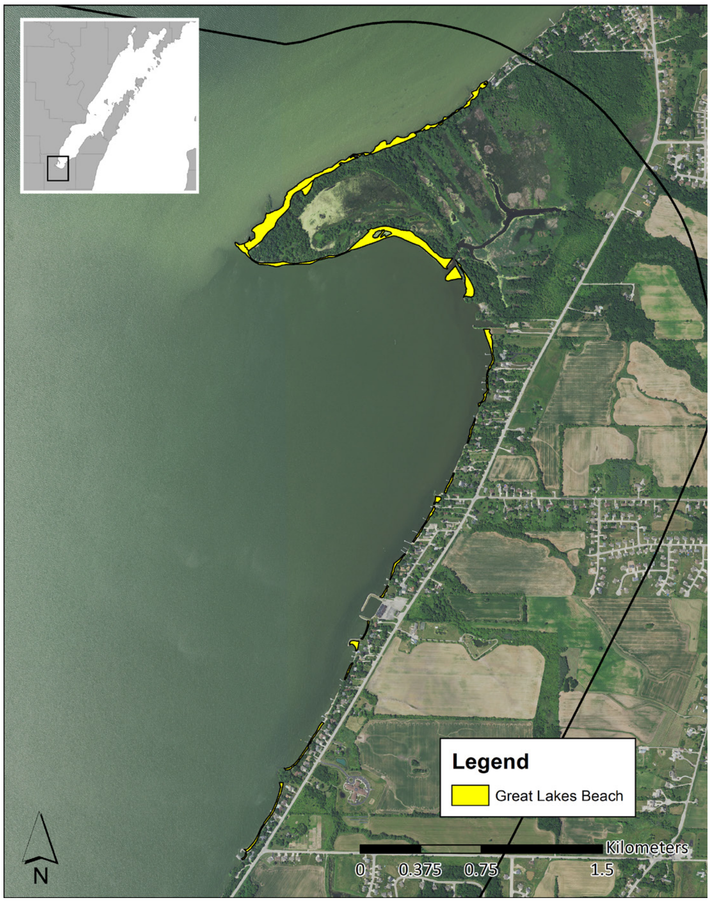


Figure 2.58. Great Lakes beach habitat in the Lower Green Bay and Fox River Area of Concern along the eastern and Point Sable shorelines. The black line shows the extent of the project study area. Basemap air photo from Brown County (2015). Map was created using ArcGIS 10.5 software (Environmental Systems Research Institute 2016).

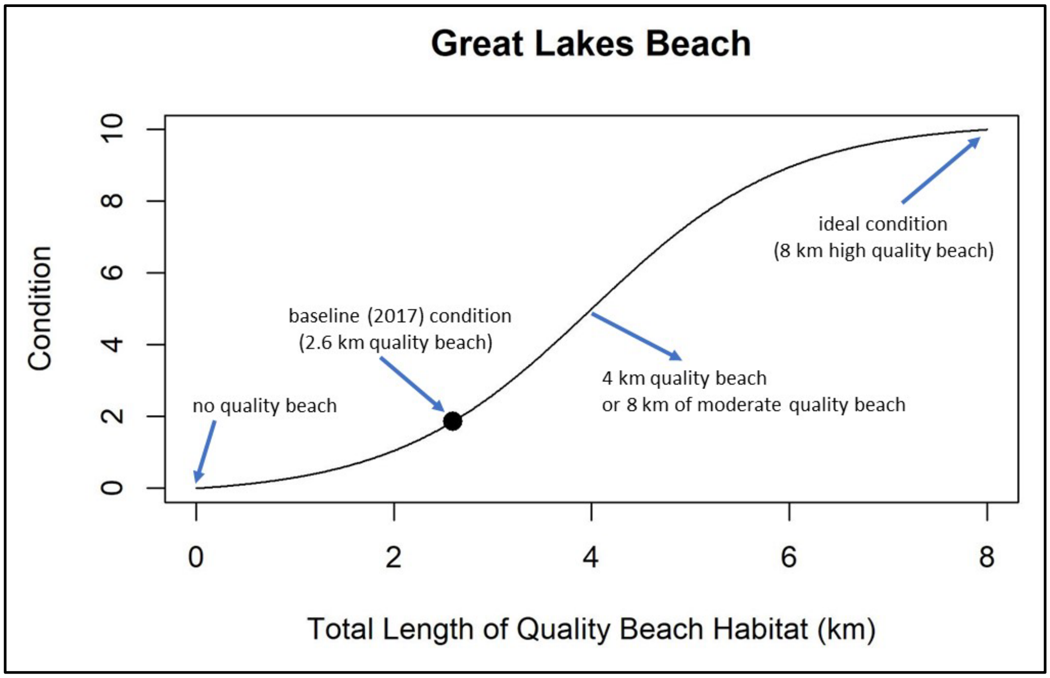


Figure 2.59. Great Lakes beach habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total length of quality beach habitat (scaled from 0 [no quality beach] to 8 [ideal beach, 8 km of high quality beach]), which is determined through field surveys, and the y-axis is the converted condition for a given length of quality beach habitat, which ranges from poor condition (0) to good/ideal condition (10).

Great Lakes beach habitat along the UW-Green Bay campus shoreline. Photograph taken by Robert Howe.

Southern Sedge Meadow

Southern sedge meadow is one of the rarest plant community types today in the LGB&FR AOC (Figure 2.60). Mostly occurring between coastal emergent marsh and shrub carr at or near water level in the Great Lakes coastal zone (Curtis 1959), this open wetland type is dominated by Canada bluejoint grass (*Calamagrostis canadensis*), tussock sedge (*Carex stricta*), and common lake sedge (*C. lacustris*). Canada bluejoint grass and tussock sedge both produce a system of short rhizomes that, over several growing seasons, will accrete to form a mound or tussock upon which new growth emerges. The abundance of these tussocks gives southern sedge meadows a distinctive physiognomy and high plant species richness (Peach and Zedler 2006). American water horehound (*Lycopus americanus*), lance-leaved panicled aster (*Symphyotrichum lanceolatum*), spotted joe-pye-weed (*Eutrochium maculatum*), marsh bellflower (*Campanula aparinoides*), and swamp milkweed (*Asclepias incarnata*) are also characteristically present in this community, along with a large diversity of other herbaceous species. However, within the LGB&FR AOC, reed canary grass (*Phalaris arundinacea*) may dominate southern sedge meadows and can sometimes form monodominant stands.

Air photos from 1938, a low-water period, show extensive areas of coastal meadows in the LGB&FR AOC that likely were dominated by tussock sedge (*Carex stricta*) and Canada bluejoint grass (*Calamagrostis canadensis*). By 1960, drainage ditches were constructed in many of these wet meadows (e.g., north of the Duck Creek Delta, Point au Sable, Atkinson’s Marsh west of the Fox River mouth), altering the topography and hydrology of these important wetlands. Later, invasion of reed canary grass (*Phalaris arundinacea*), *Phragmites australis,* and hybrid cattail (*Typha × glauca*) further altered these wetlands, leaving just small remnants of native southern sedge meadow habitat. *Carex*/*Calamagrostis* meadows today have been replaced almost entirely by mosaics of weedy forbs and non-native grasses or nearly monotypic stands of hybrid cattail during high water periods.

Another threat to the diversity of southern sedge meadow habitats in the LGB&FR AOC is the encroachment of shrubs and trees. Occasional fires prevent woody succession, but drainage ditches and fire suppression have allowed shrubs and trees to invade and remain established in areas that were once open wet meadows.

Although extensive tracts of southern sedge meadow have disappeared from the LGB&FR AOC, small but quality examples of southern sedge meadow occur at Point au Sable, Fort Howard Wildlife Area, and the Malchow/Olson Tract (not found during the 2015 habitat mapping effort). Bird species, such as Sandhill Crane (*Antigone canadensis*), American Bittern (*Botaurus lentiginosus*), Yellow Rail (*Coturnicops noveboracensis*), and Sedge Wren (*Cistothorus platensis*), use southern sedge meadow for nesting habitat (Mossman and Sample 1990). Other rare or uncommon animal species also may occur in large, high quality sedge meadows, including Blanding’s turtle (*Emydoidea blandingii*) and sensitive wetland insects like the skippers Dion skipper (*Euphyes dion*), broad-winged skipper (*Poanes viator*), and mulberry wing (*Poanes massasoit*; Miller et al. 2009).

Southern sedge meadow is one of two habitat types with the highest priority weight (=14). This habitat type was much more abundant historically, but only a few relatively small sites remain in the LGB&FR AOC today. In Wisconsin overall, Mossman and Sample (1990) reported that less than 3% of the pre-settlement area of sedge meadows remains. Southern sedge meadow has a State Rank of S3 (=vulnerable) in Wisconsin. Werner and Zedler (2002) suggested that the complex microtopography of *Carex* tussocks promotes high species diversity compared with weedy *Phalaris* meadows. Accumulation of sediments reduces substrate complexity and might contribute to the loss of native sedge meadow species. Eutrophication of wet meadows by runoff from urban and suburban landscapes also promotes the replacement of *Carex* meadows by hybrid cattail (Woo and Zedler 2002), a phenomenon that seems to have occurred widely in the LGB&FR AOC.

The current condition for southern sedge meadow habitat is low (=2) in the LGB&FR AOC. Remaining sites are small and continue to be threatened by invasive species. Habitat restoration should be a high priority at remaining southern sedge meadow sites and perhaps other sites where sedge meadows once occurred (e.g., north of the Duck Creek delta and along Wequiock Creek at Point au Sable). This will not be an easy task. The combined effects of altered hydrology, excess nutrients, and invasive plant species need to be overcome at sites targeted for restoration (Zedler 2000). Hall and Zedler (2010) recommend aggressive harvesting and control of invasives like hybrid cattail, allowing *Carex* tussocks to reproduce vegetatively, gradually expanding into coastal areas that undergo periodic flooding or are subject to poor drainage.

Southern sedge meadows in the coastal zone of lower Green Bay and the Fox River will never be restored to their pre-settlement condition. Nevertheless, we recommend an ideal and realistic future condition of 60 ha (approximately 150 acres) of high-quality southern sedge meadow habitat. Once this target is reached, a commitment to long-term, active stewardship will be needed to combat ongoing threats from invasive species, altered hydrology, and cultural eutrophication. The assessment curve is non-linear (Figure 2.61), reflecting the idea that any additions to the extent of this important habitat will be immediately beneficial in providing refugial habitat for plants and several (small) animals. Restoration efforts will have a very positive impact over the range of 0-30 ha, with some degree of diminishing returns after 30 ha of habitat has been protected or restored.

For more information on this habitat, visit the WDNR's Southern Sedge Meadow webpage: http://dnr.wi.gov/topic/EndangeredResources/Communities.asp?mode=detail&Code=CPHER062WI.

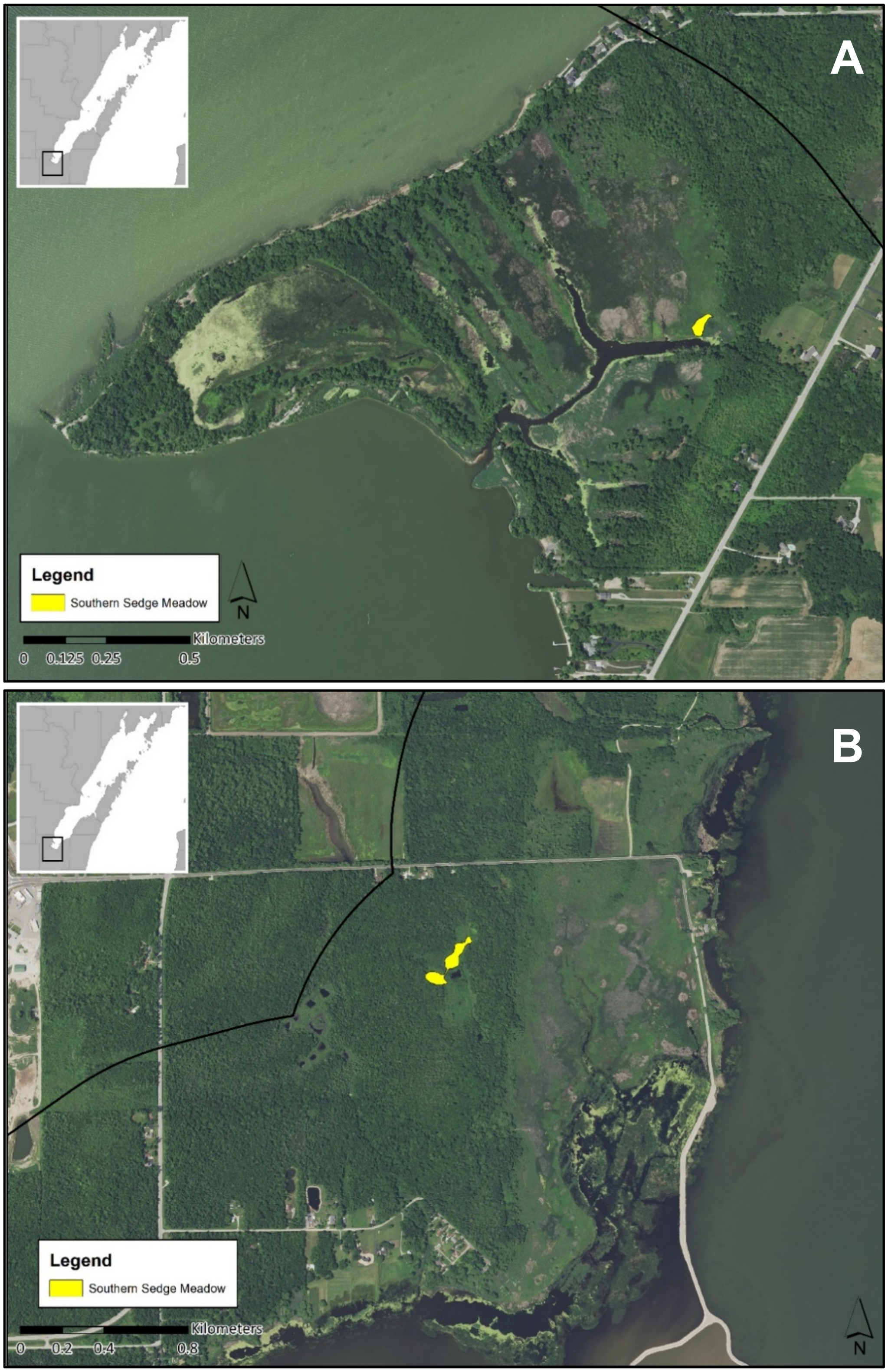


Figure 2.60. Southern sedge meadow habitat in the Lower Green Bay and Fox River Area of Concern at Point Sable (A) and Fort Howard Wildlife Area (B). Maps were created using ArcGIS 10.5 software (Environmental Systems Research Institute 2016). The black line shows the extent of the project study area. Basemap air photo from Brown County (2015). Note that a small patch of southern sedge meadow was found on the Malchow/Olson Tract in 2016, after the 2015 habitat mapping, which is why it is not shown above.

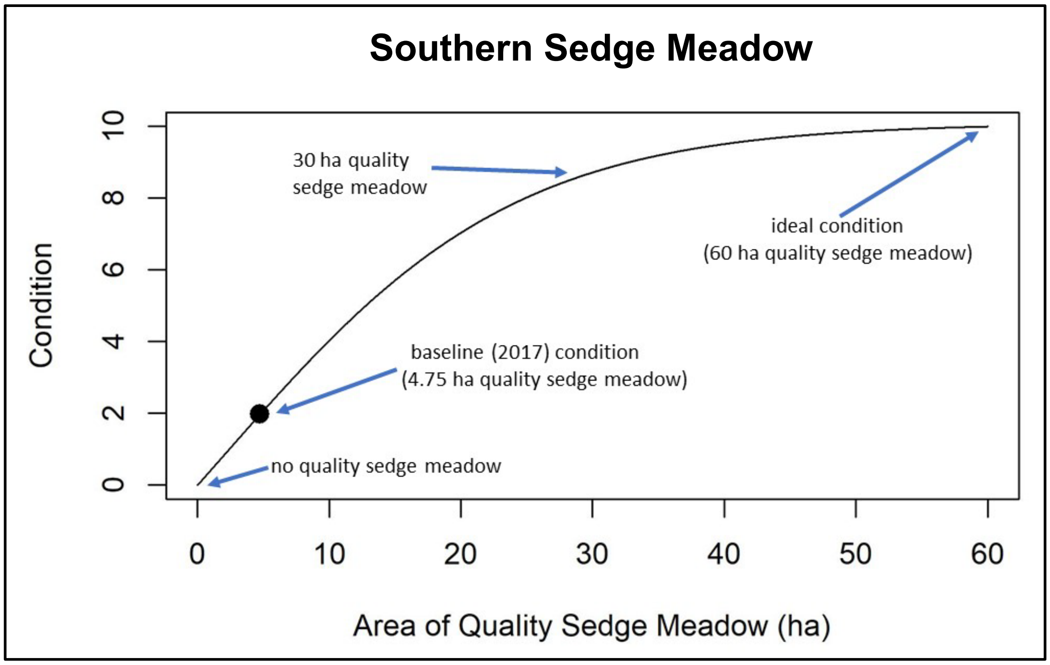


Figure 2.61. Southern sedge meadow habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total area of quality southern sedge meadow habitat (scaled from 0 [no quality sedge meadow] to 60 [ideal sedge meadow, 60 ha of quality sedge meadow]), which is determined through field surveys. The y-axis is the converted condition for a given area of quality sedge meadow habitat, which ranges from poor condition (0) to good/ideal condition (10).

Southern sedge meadow habitat on the Malchow/Olson Tract. Photograph taken by James Horn in 2016.

Emergent Marsh (high energy coastal)

Coastal wetlands dominated by emergent macrophytes along shorelines and bays comprise one of the most extensive habitat types in the LGB&FR AOC. Soils are typically inundated for much of the year and consist of organic mucks overlaying circumneutral to alkaline bedrock. Exposure to waves creates a high energy environment that can be especially severe along north-exposed shorelines of the lower bay. These coastal wetlands, in turn, may provide a valuable ecological service by buffering wave effects and preventing shoreline erosion (Shepard et al. 2011). Dominant native species include cattails (*Typha* spp., historically *T. latifolia*), bulrushes (*Schoenoplectus* spp.), river bulrush (*Bolboschoenus fluviatilis*), bur-reeds (*Sparganium* spp.), arrowheads (*Sagittaria* spp.), true rushes (*Juncus* spp.), and spikerush (*Eleocharis* spp.). Covering 20% of the AOC, coastal emergent marshes are now characteristically dominated by two invasive species, common reed (*Phragmites australis* subsp. *australis*) and hybrid cattail (*Typha* × *glauca*). Reed canary grass (*Phalaris arundicacea*) is a frequent, invasive dominant of the inland zone of emergent marshes, and its dominance may continue inland to southern sedge meadow communities. Native plant diversity, including both emergent and submergent vegetation, creates a healthy ecosystem and important resources for fish and wildlife species, including spawning and nursery habitat for fish and anurans. The plants provide oxygen and filter the water by absorbing certain nutrients and preventing algal blooms. Emergent wetlands also may have a positive effect on water clarity by reducing wind resuspension of sediments. Marsh birds, such as rails, Marsh Wren (*Cistothorus palustris*), Pied-billed Grebe (*Podilymbus podiceps*), Least Bittern (*Ixobrychus exilis*) and others, use coastal marshes extensively for feeding and nesting.

Although wave action and exposure to turbid water from the Fox River and other Green Bay tributaries may constrain the integrity of coastal emergent marsh vegetation, connection to the bay is critical for fish access and sustaining habitat diversity and high productivity (Jude and Pappas 1992). Brazner and Beals (1997), Brazner (1997), and others have demonstrated that coastal wetlands in Green Bay, particularly those that are minimally influenced by development, provide vital habitat for economically and ecologically important fish species.

This historically important habitat was rated with the second highest priority weight (13). The current condition of emergent marsh (high energy coastal and inland), while extensive and biologically productive in the LGB&FR AOC, was assigned a current condition of only 4 because of the widespread occurrence of non-native and aggressive common reed and hybrid cattail. High energy coastal, emergent marsh habitat can be found throughout the LGB&FR AOC at Point au Sable, UW-Green Bay campus, Bay Beach Amusement Park Shoreline, Ken Euers Nature Area, Duck Creek, Peter's Marsh, Cottage Grove Complex, Malchow/Olson Tract, Long Tail Point, Dead Horse Bay, and Sensiba South. Virtually all of these areas are invaded by *Phragmites* and *Typha* × *glauca*, although high water levels during recent years (2016-17) have helped promote increased plant species diversity at many of these sites.

We propose a desired ideal future condition of 600 ha of high quality emergent marsh, where high quality is defined as wetland with few invasive species, high mean coefficient of conservatism (CC) of plant species, a favorable mix of open water and vegetation, and high species richness. The current extent of coastal emergent marsh is more than 500 ha, so the primary conservation actions to reach this target will be to improve the condition of existing wetland habitats. Several researchers have demonstrated the importance of interspersion of marsh vegetation and open water (Rehm and Baldassarre 2007, Tozer et al. 2010, Bolenbaugh et al. 2011) for wetland breeding birds. Natural disturbances such as wind or ice damage, flooding, and herbivory by muskrats, create heterogeneous marsh habitat for species that use dense vegetation for nesting but open water for feeding. Preserving or promoting a natural disturbance regime therefore should be a part of long-term conservation of high energy coastal marsh. In the LGB&FR AOC. Diked wetlands provide some opportunity to control wetland disturbance dynamics, but mismanagement of these artificial systems might promote the spread of invasive species and reduce the importance of coastal wetlands as fish habitat (Wilcox and Whillans 1999, Herrick and Wolf 2005, Monfils et al. 2015).

The extent and quality of coastal emergent marsh habitat can be assessed by GIS analysis combined with field surveys. Methods described by Uzarski et al. (2017) provide guidance for determining wetland quality; a specific recipe for quantifying wetland habitat quality in Green Bay and the Fox River needs to be refined, however. Croft et al. (2007) and Lougheed et al. (2011) have shown that certain wetland plants in the Great Lakes basin are intolerant of turbid, eutrophic waters, while others are more tolerant of polluted systems, providing a foundation for development of a local metric for the LGB&FR AOC. Until quantitative protocols and metrics are developed, subjective assessments of wetland quality can be used to apply the condition curve that we propose (Figure 2.62). For example, 500 ha of moderate quality wetland (condition = 5 on a scale from 0-10) will be equivalent to 250 ha of high-quality wetland (condition = 10 on a scale form 0-10). Our goal is to develop an objective method for quantifying the 0-10 condition score; the number of hectares can be measured directly form aerial imagery, although some mechanism is needed to account for the natural fluctuations in area due to water level variability.

For more information on this habitat, visit the WDNR's Emergent Marsh webpage: http://dnr.wi.gov/topic/EndangeredResources/Communities.asp?mode=detail&Code=CPHER056WI.

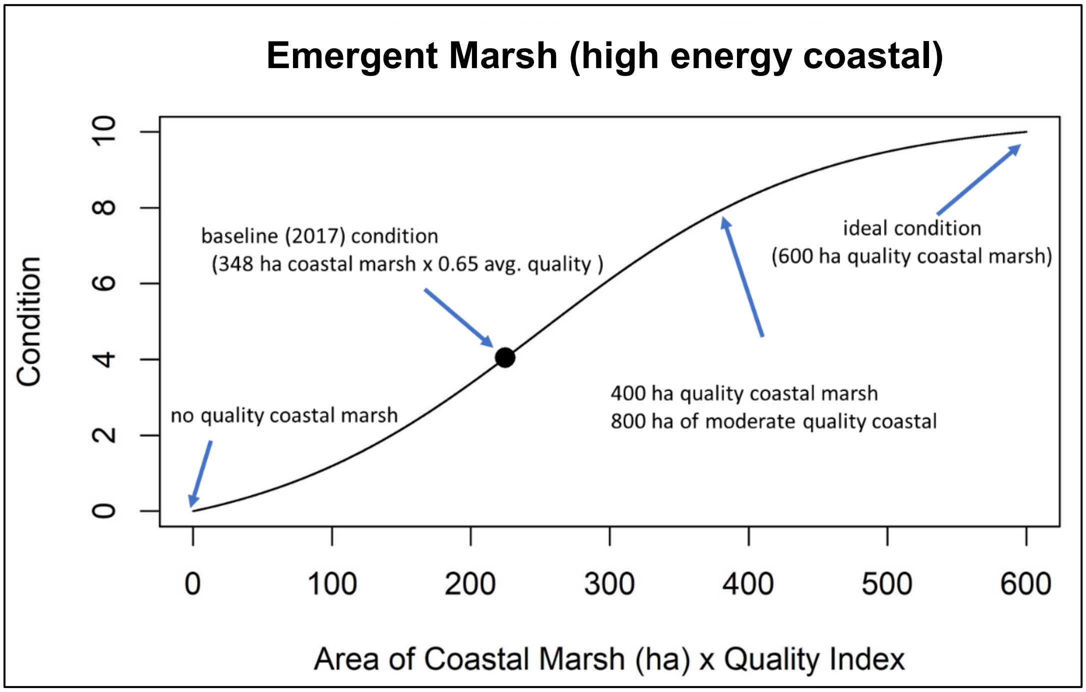


Figure 2.62. Emergent marsh (high energy coastal) habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total area of quality emergent marsh (high energy coastal) habitat (scaled from 0 [no quality coastal marsh] to 600 [ideal coastal marsh, 600 ha of quality coastal marsh]), which is determined through field surveys. The y-axis is the converted condition for a given area of quality coastal marsh habitat, which ranges from poor condition (0) to good/ideal condition (10).

Emergent marsh (high energy coastal) habitat along the Malchow/Olson Tract coastline. Photograph taken by Robert Howe, 2016.

Submergent Marsh

Submergent marsh, an aquatic habitat comprised of submerged aquatic vegetation (SAV), occurs in lakes, ponds, and rivers, commonly at depths between 0.2 m and 3.0 m. In the LGB&FR AOC, submergent marsh accounts for about 10% of the study area that we have defined (Figure 2.63). SAV in this ecosystem consists of species from 12 plant families that have highly modified growth forms and exist as fully submergent or floating leaf macrophytes. Characteristic native dominants include sago pondweed (*Stuckenia pectinata*), true pondweeds (*Potamogeton* spp., especially *P. foliosus* and *P. nodosus*), waterweeds (*Elodea canadensis* and *E. nuttallii*), eel-grass (*Vallisneria americana*), water-milfoil (*Myriophyllum* spp., especially *M. sibiricum*), bladderworts (*Utricularia* spp., especially *U. vulgaris*), and coontail (*Ceratophyllum demersum*). Duckweeds (*Lemna minor* and *L. turionifera*; *Spirodela polyrrhiza*; *Wolffia* spp.) are ubiquitous as floating-leaved macrophytes. Members of the water-lily family *(Nymphaea odorata* and *Nuphar variegata*) may also be present in submergent marshes that are protected from strong wave action. Three invasive submergent species, namely Eurasian water milfoil (*Myriophyllum spicatum*), curly-leaf pondweed (*Potamogeton crispus*), and eutrophic water-nymph (*Najas minor*), are occasionally present in submergent marshes of the LGB&FR AOC, but infrequently become dominants. Many ecological factors affect the species composition of submergent marshes, including water depth, water chemistry, water movement, and bottom substrate. Submergent marshes are distinct from mats of the nuisance filamentous green macroalga *Cladophora glomerata*, which occurs widely in the Great Lakes and appears to have increased since the widespread establishment of dreissenid mussels (Higgins et al. 2008, Althouse et al. 2014).

Much like emergent marsh communities, submergent marshes may help enhance water quality by acting as a nutrient sink and enhancing nitrification/denitrification processes in the benthos (Kufel and Kufel 2002). Studies in Florida have demonstrated that SAV is particularly effective in sequestering phosphorus from polluted waters (Dierberg et al. 2002). The plant community of submergent marshes stabilizes lake and river bottoms, reduces shoreline erosion, and improves water clarity by reducing resuspension of sediments (Dennison et al. 1993). Many fish species use submergent marshes for feeding, spawning, and predator avoidance (Rozas and

Odum 1988). Ducks and waterfowl forage on many SAV species, especially eel grass (Crowder and Bristow 1988, Knapton et al. 1999).

Because this is a historically important, ecologically influential, and still extensive habitat, submergent marsh (submerged aquatic vegetation) was assigned a priority weight of 13, the second highest value in our list of 18 habitat types. In the LGB&FR AOC, submergent marshes are found at Point au Sable, UW-Green Bay campus, Bay Beach Wildlife Sanctuary, Abbey Pond, Ashwaubomay Park, bay of Green Bay, Duck Creek, Ken Euers Nature Area, Malchow/Olson Tract, and Longtail Point (Figure 2.63). Based on field surveys and discussions with local biologists, we estimated the current condition of submergent marsh in the LGB&FR AOC to be 5 on the 0-10 scale. Turbidity is currently a serious problem in the LGB&FR AOC, and impaired water clarity surely limits the extent of submergent marsh in the lower bay and Fox River.

The potential for improving the condition of SAV in the LGB&FR AOC seems to be high. At Point au Sable, for example, elimination of dense, monotypic *Phragmites* stands between 2012 and 2015 coupled with rising water levels led to a dramatic re-establishment of native SAV in the coastal lagoon, without any artificial planting or translocation of species. Patrick et al. (2016) found that shoreline armoring reduces the growth of SAV in Chesapeake Bay, suggesting that removal of bulkhead, riprap, and other artificial shoreline features may be an effective contributor to increased extent of SAV in estuarine ecosystems like the LGB&FR AOC.

Restoration of SAV in shallow lakes has been well-studied in Europe, and guidelines for re-establishment of desirable species have been presented by Hilt et al. (2006) and others. Many of their recommendations (e.g., dredging removal of phosphorus rich sediments) are not applicable to large, wind-affected systems like lower Green Bay, but the importance of water clarity in restoring and maintaining SAV is highly relevant. Construction of nearshore structures that reduce turbidity and sediment resuspension likely will promote SAV growth in affected shallow waters.

Our recommended assessment metric follows the general pattern that we have outlined for other habitats. Croft and Chow-Fraser (2007) developed an aquatic macrophyte index for quantifying vegetation quality. We will develop a multispecies index following their guidance and the general IEC approach (Howe et al. 2007), where species-specific responses to a disturbance gradient are employed to estimate the condition of sites where these species are sampled. The conversion curve (Figure 2.64) is non-linear, reflecting the fact that even modest areas of SAV are critical for fish habitat, and high condition scores are attainable well below the maximum desired extent of submergent marsh (200 ha+) in the LGB&FR AOC.

For more information on Submergent Marsh in Wisconsin, visit the WDNR's webpage: http://dnr.wi.gov/topic/EndangeredResources/Communities.asp?mode=detail&Code=CPHER058WI.

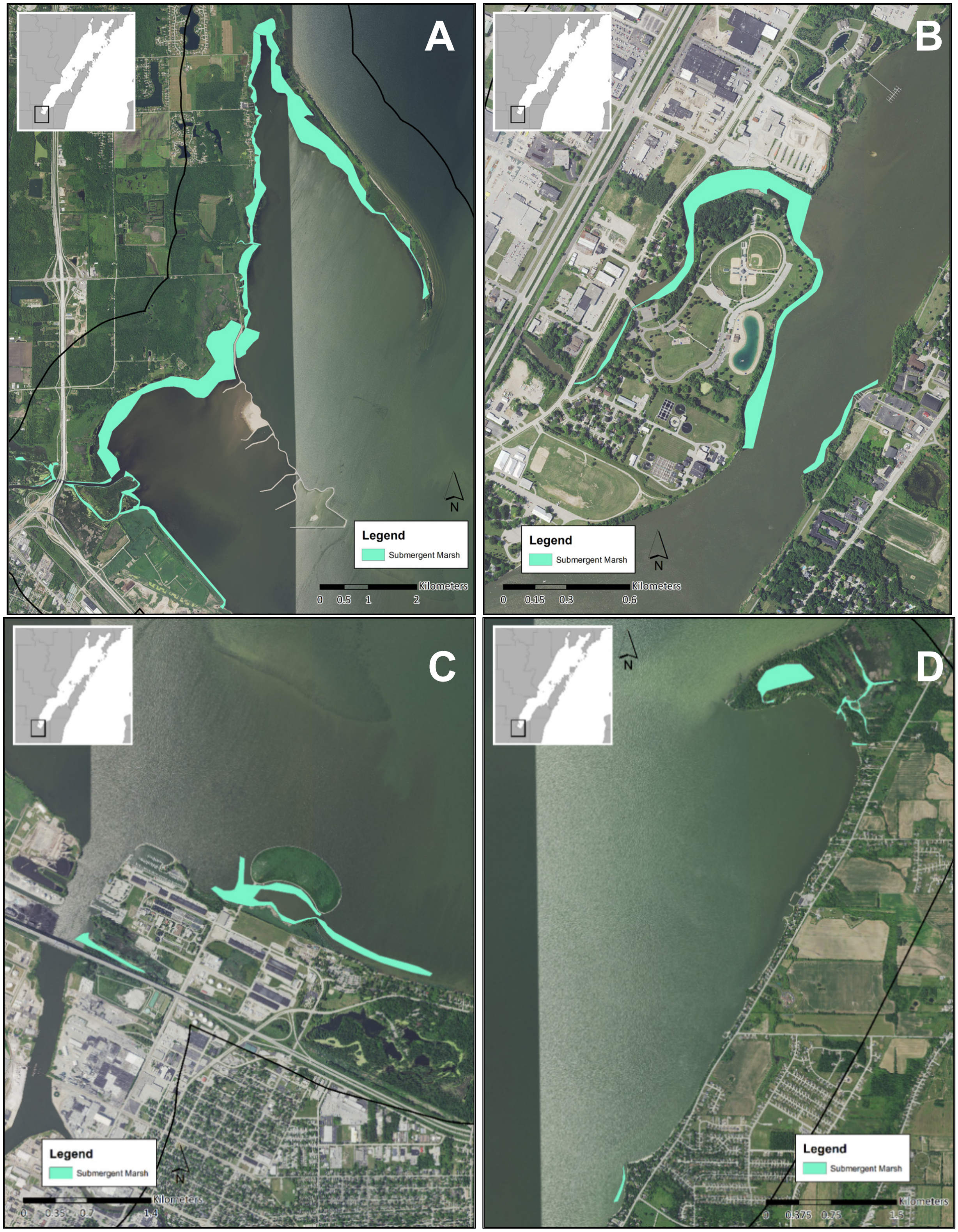


Figure 2.63. Submergent marsh in the Lower Green Bay and Fox River Area of Concern: A) West shore of the bay of Green Bay, B) Ashwaubenon Creek along the Fox River, C) Bay Beach Amusement Park shoreline and Fox River wetland inlet, and D) East shore of the bay and Point Sable. Marshes were delineated in fall 2017. The black line shows the extent of the project study area. Basemap air photo from Brown County (2015). Maps were created using ArcGIS 10.5 software (Environmental Systems Research Institute 2016).

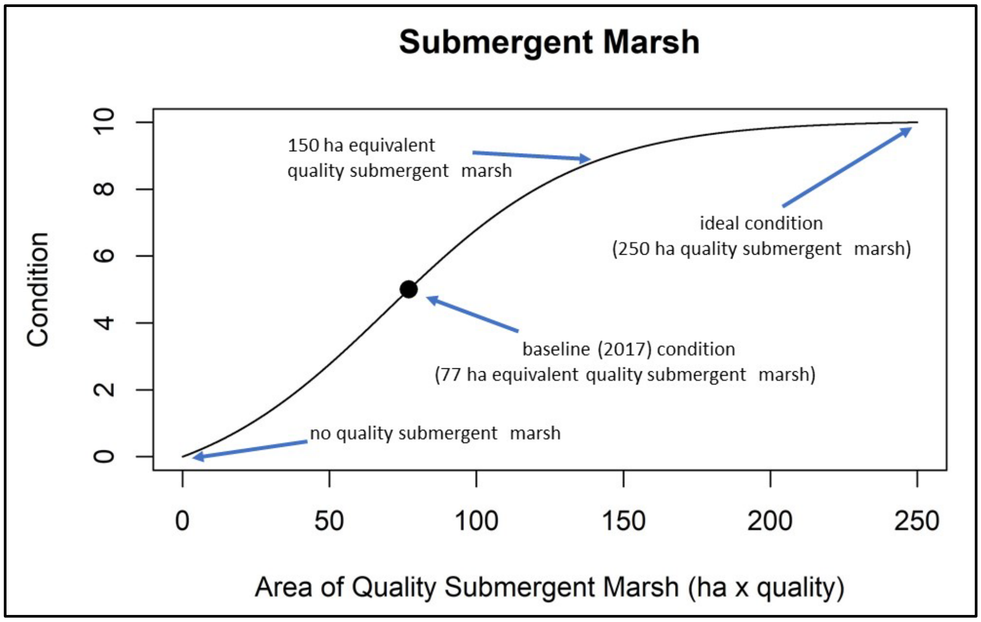


Figure 2.64. Submergent marsh habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total area of quality submergent marsh habitat (scaled from 0 [no quality submergent marsh] to 250 [ideal submergent marsh, 250 ha of quality submergent marsh]), which is determined through field surveys, and the y-axis is the converted condition for a given area of quality submergent marsh habitat, which ranges from poor condition (0) to good/ideal condition (10).

Submergent marsh habitat in the mouth of Duck Creek. Photograph taken by Thomas Prestby in July 2015.

Emergent Marsh (riparian)

This community is an open wetland on mineral soils along the banks of slow-moving rivers and streams. Marsh soils are inundated for much of the year, and the vegetation consists of emergent macrophytes. Dominant native plants include cattails (*Typha latifolia*), bulrushes (*Schoenoplectus* spp., *Bolboschoenus fluviatilis*), arrowheads (*Sagittaria* spp.), spikerush (*Eleocharis* spp.). Covering about 2% of the LGB&FR AOC, riparian emergent marshes are now dominated by three invasive species: common reed (*Phragmites australis* subsp. *australis*), reed canary grass (*Phalaris arundinacea*), and hybrid cattail (*Typha* × *glauca*). Plant diversity, including both emergent and submergent vegetation, create a healthy ecosystem. The plants provide oxygen and filter the water by absorbing certain nutrients and preventing algal blooms. Riparian emergent marshes also provide safe spawning habitat for fish and nesting habitat for birds and amphibians.

Emergent marsh (riparian) occurs sparsely in the LGB&FR AOC at the Leo Frigo Memorial Bridge near the mouth of the Fox River, Ashwaubenon Creek, Ashwaubomay Park, Duck Creek, and Sensiba South. We estimate that up to 80 ha of quality riparian emergent marsh can be restored and maintained in the LGB&FR AOC, a realistic ideal condition for our assessment metric (Figure 2.65). We recommend a non-linear measure of emergent marsh (riparian) habitat, weighted by quality on a scale from 0 to 1. Converted to our standard scale, 80 ha of high-quality emergent marsh (riparian) habitat (quality = 1) would yield a maximum condition score of 10. Based mainly on our field surveys, the overall current condition for emergent marsh (riparian) habitat is fairly low (=3). Most of these areas in the LGB&FR AOC are in poor condition, being heavily invaded by Phragmites or other non-native plants. However, actively managing these invasive plants can greatly enhance this important habitat. Improving this habitat will in turn improve streams and other waterways.

For more information on this habitat, visit the WDNR's Emergent Marsh webpage: http://dnr.wi.gov/topic/EndangeredResources/Communities.asp?mode=detail&Code=CPHER056WI.

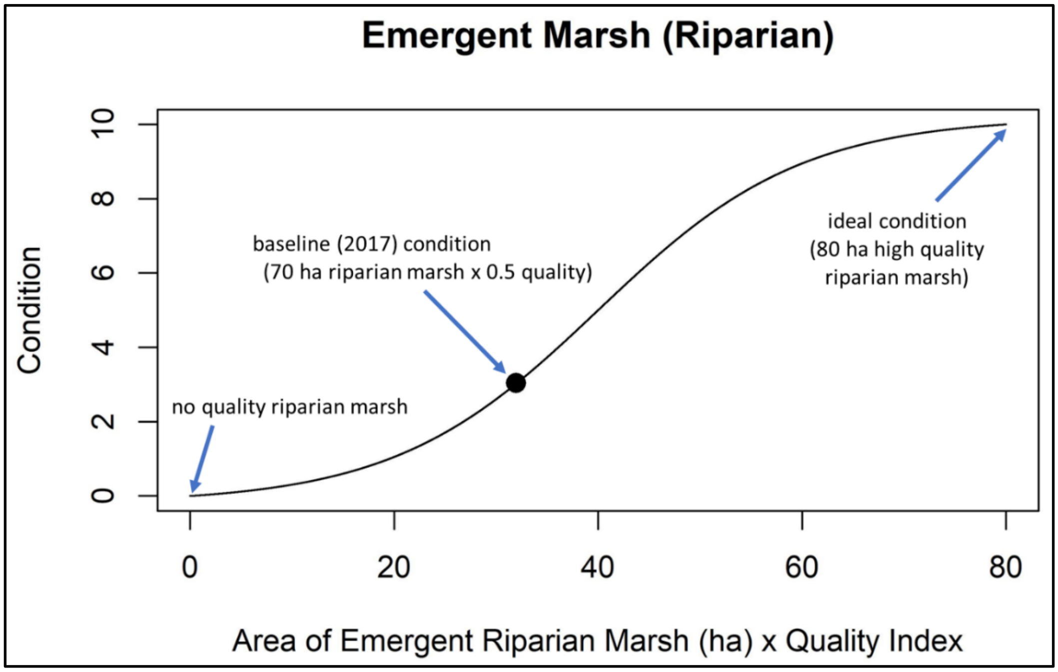


Figure 2.65. Emergent marsh (riparian) habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total area of quality emergent marsh (riparian) habitat (scaled from 0 [no quality emergent marsh riparian] to 80 [ideal emergent marsh riparian, 80 ha of quality emergent marsh riparian]), which is determined through field surveys, and the y-axis is the converted condition for a given area of quality emergent marsh (riparian) habitat, which ranges from poor condition (0) to good/ideal condition (10).

Emergent marsh (riparian) habitat along the shores of Duck Creek. Photograph taken by Thomas Prestby in July 2015.

Fox River Open Water

This habitat type refers to the open water of the Fox River (i.e., lower Fox River), which is a third order stream that flows northeast starting from Lake Winnebago and emptying into the bay of Green Bay. Within the LGB&FR AOC, this open water category runs from the De Pere Dam to the mouth of the Fox River. The shipping channel in the lower bay of Green Bay continues down the Fox River roughly 6.5 km upstream to the south with depths of up to 7.32 km (24 ft) in the river. Waters along the eastern and western shorelines of the Fox River range from 0.30-1.22 km (1-4 ft) deep. Sediments consist of sand and clay. The East River, Ashwaubenon Creek, and Dutchman Creek are smaller second order streams that empty into the Fox River. Critical fish spawning habitat occurs in this community type by the De Pere Dam for lake sturgeon (*Acipenser fulvescens*), walleye (*Sander vitreus*), smallmouth bass (*Micropterus dolomieu*), and lake whitefish (*Coregonus clupeaformis*). Other spawning reefs and areas are located along the edges of the Fox River. Waterways by the De Pere Dam Fox River are known for being hosting a world-class walleye fishery. Two submergent marshes are located along the eastern shoreline by the Fox Point Boat Launch and in the outer reaches and mouth of Ashwaubenon Creek adjacent to the Fox River on the western Fox River shoreline. Besides fish, odonates (dragonflies + damselflies), birds (especially waterfowl and waterbirds), bats, anurans (frogs + toads), and turtles use the waterways, air space, and/or terrestrial riparian habitats of the Fox River open water community. (Summary information on fish usage based on research conducted by Wisconsin Department of Natural Resources' Steve Hogler, Brown County's Charles Larscheid, and others.)

We recommend a linear measure of Fox River open water habitat that uses a water quality index, which has still yet to-be-determined (Figure 2.66). Based on expert opinion, the overall current condition for Fox River open water habitat is fairly low (=3) due to poor water quality.

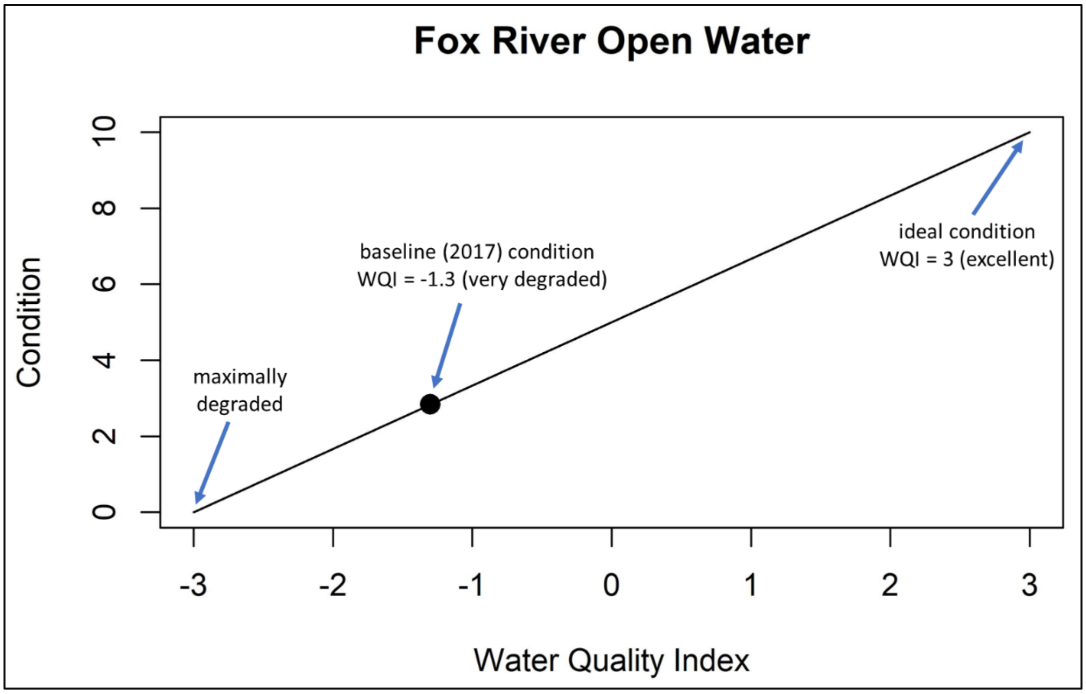


Figure 2.66. Fox River open water conversion curve for the Lower Green Bay and Fox River Area of Concern. The x-axis represents a water quality index (scaled from -3 [poor] to 3 [high]), which is determined through field surveys, and the y-axis is the converted condition, which ranges from poor condition (0) to good/ideal condition (10).

Fox River open water habitat facing south-southwest towards De Pere Dam. Photograph taken by Erin Giese in December 2016.

Green Bay Open Water

Green Bay open water consists of the open water/pelagic zone of the lower bay of Green Bay, which is the western arm of Lake Michigan. Shallow areas range from roughly 0.30 m to 1.83 m in depth to deeper areas that can be up to 4.88 m deep, with the exception of the shipping channel, which can be up to 7.32-7.92 m deep. 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. Sediments largely consist of sand and silt.

Special features include Point Sable Bar and Frying Pan Shoal, which is a drowned sandbar that extends from Point Sable on the eastern shoreline of the bay to Long Tail Point on the west shore. Historically, in low water years, Native Americans used to walk on foot from Point Sable to the west shore. To the southeast of the mouth of the Fox River is Renard Island, which is a confined disposal facility used for storing shipping channel dredge material. There is a fish spawning reef around Renard Island, the McDonald Marina, and Joliet Park. The Cat Island Chain Restoration Site on the west shore, which consists of a >3 km-long causeway, was constructed to restore the historic barrier islands of the Cat Island Chain for fish and wildlife habitat while simultaneously filling shipping channel dredge material in the island "cells." Extensive submergent marshes line the outer edges of the Green Bay open water community, particularly along the west shore in Dead Horse Bay and the mouth of Duck Creek in the southwest corner of the bay.

Over 80 species of fish have been reported in the Green Bay open water community, many waterfowl species use these waters during migration, colonial nesting birds utilize the bay's islands for breeding, and invertebrates use the water and nearshore habitat. We recommend a linear measure of Green Bay open water habitat that uses a water quality index, like for the Fox River, which has still yet to-be-determined (Figure 2.67). Based on expert opinion, the overall current condition for Green Bay open water habitat is fairly low (=3) due to poor water quality.

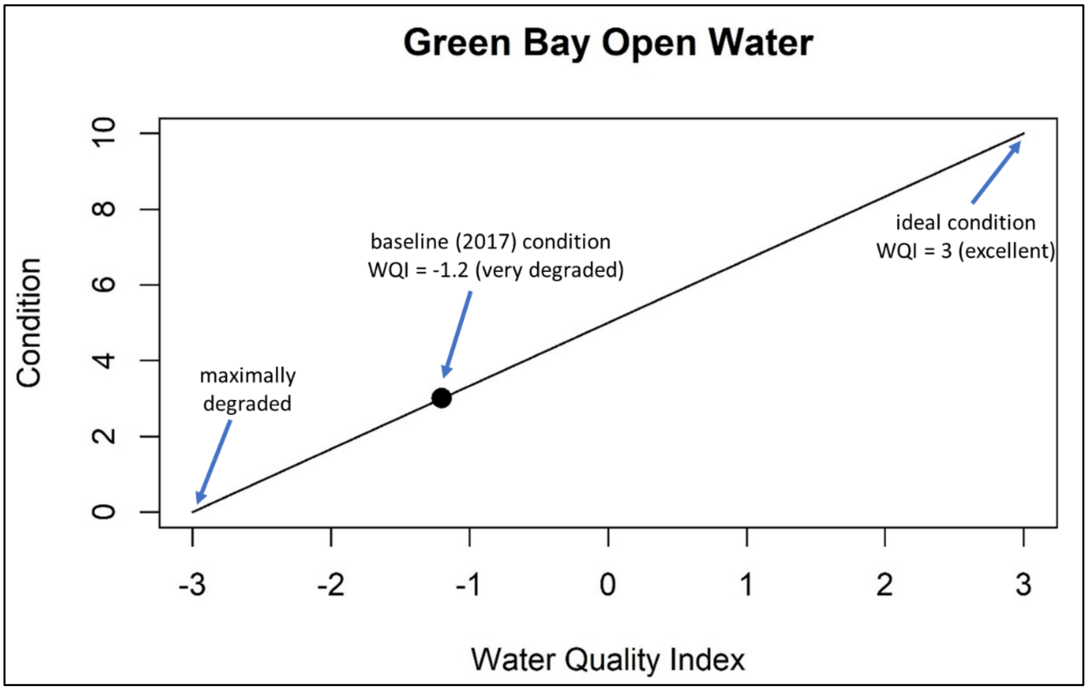


Figure 2.67. Green Bay open water conversion curve for the Lower Green Bay and Fox River Area of Concern. The x-axis represents a water quality index (scaled from -3 [poor] to 3 [high]), which is determined through field surveys, and the y-axis is the converted condition, which ranges from poor condition (0) to good/ideal condition (10).

Green Bay open water habitat facing Lone Tree Island. Photograph taken by Katie Crews in July 2015.

Shrub Carr

Shrub carr covers around 4% of the LGB&FR AOC and is a transitional community type that occurs between open wetlands and forested wetlands. Hence, it occurs in close proximity to bodies of water and may develop near rivers, ponds, and lakes. This wetland community is dominated by broadleaf, deciduous shrubs that can spread clonally by means of rhizomatous growth. Shrubby willow species (*Salix* spp., especially *S. petiolaris*, *S. eriocephala*, and *S. interior*) are typically aspect dominant, along with red-osier dogwood (*Cornus sericea*), silky dogwood (*C. amomum*), and meadowsweet (*Spiraea alba*). The native herbaceous species composition of LGB&FR AOC shrub carr is similar to that of southern sedge meadows, and these two plant community types often appear form a mosaic in less disturbed coastal habitats. Glossy buckthorn (*Frangula alnus*) is the most common woody invasive species of shrub carr but appears to be less competitive in this community type than in hardwood swamp forests. Reed canary grass (*Phalaris arundinacea*), purple loosestrife (*Lythrum salicaria*), and, to a lesser extent, common reed (*Phragmites australis* subsp. *australis*), are problematic invaders of the herbaceous stratum, and displace native graminoids and forbs.

Alder thicket, dominated by speckled alder (*Alnus incana* var. *rugosa*), may occupy the same zone in the transition from open, wetland plant communities to forests. This shrub-dominated wetland community is now rare in the LGB&FR AOC, present only on the Malchow/Olson Tract, where it occurs in close proximity to the shore of the bay of Green Bay. Edge- or shrub-associated bird species, such as Willow Flycatcher (*Empidonax traillii*) and Common Yellowthroat (*Geothlypis trichas*), use shrub carr for nesting habitat.

In the LGB&FR AOC shrub carr is found at Abbey Pond, Duck Creek, Peter's Marsh, Fort Howard Wildlife Area, Malchow/Olson Tract, Barkhausen Waterfowl Preserve, and Sensiba South. It is most common and best developed on the west shore of the bay of Green Bay. We estimate that up to 100 ha of quality shrub carr can be restored and maintained in the LGB&FR AOC, a realistic ideal condition for our assessment metric (Figure 2.68). We recommend a non-linear measure of shrub carr habitat, weighted by quality on a scale from 0 to 1. Converted to our standard scale, 100 ha of high-quality shrub carr habitat (quality = 1) would yield a maximum condition score of 10. Based mainly on our field surveys, the overall current condition for shrub carr habitat is low (=4). Some of these areas in the LGB&FR AOC are in poor condition due to them being heavily invaded by glossy buckthorn and other invasive plants. However, actively managing for these invasive shrubs can greatly enhance this important habitat.

For more information on this habitat, visit the WDNR's Shrub Carr webpage: http://dnr.wi.gov/topic/EndangeredResources/Communities.asp?mode=detail&Code=CPSHR050WI.

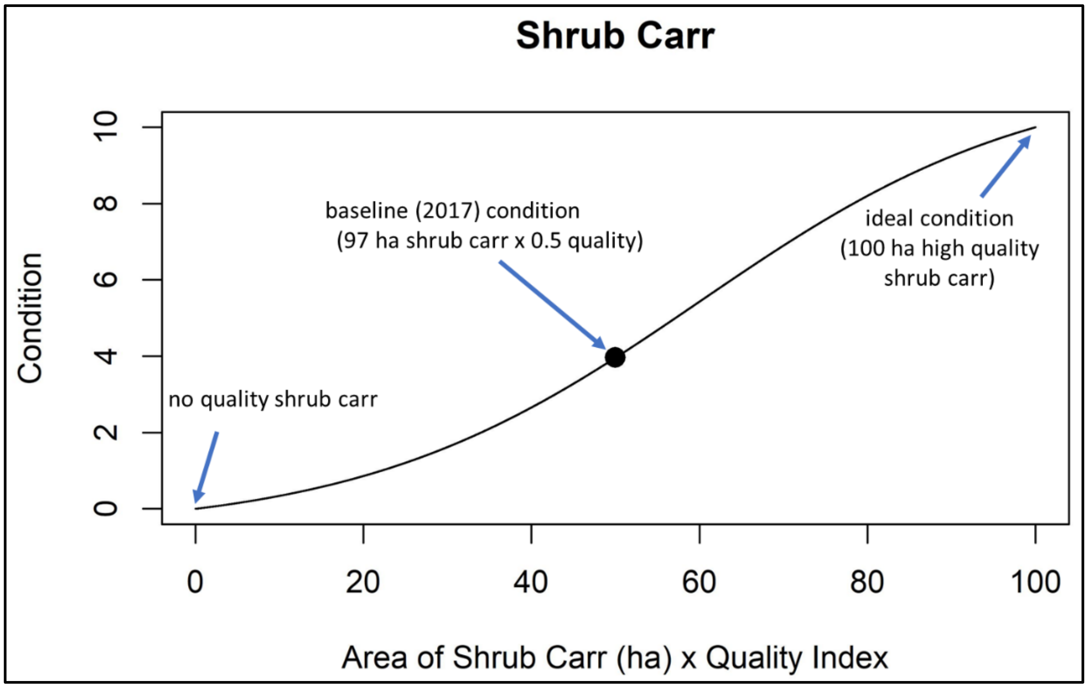


Figure 2.68. Shrub carr habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total area of quality shrub carr habitat (scaled from 0 [no quality shrub carr] to 100 [ideal shrub carr habitat, 100 ha of quality shrub carr]), which is determined through field surveys, and the y-axis is the converted condition for a given area of quality shrub carr habitat, which ranges from poor condition (0) to good/ideal condition (10).

Shrub carr habitat in Duck Creek Estuary North. Photograph taken by Katie Crews in July 2015.

Tributary Open Water

This habitat type refers to the open water of tributaries whose boundaries fall within the LGB&FR AOC study area (Figure 2.69); nearly every river, stream, and creek found within these boundaries empty into the bay of Green Bay or the Fox River. Significant streams found along the east shore of the LGB&FR AOC are Wequiock Creek, which flows through the Town of Scott and Point Sable, and Mahon Creek, which traverses through the UW-Green Bay campus. Along the eastern shoreline of the Fox River just north of the Main Street bridge is the East River. On the Fox River's western shoreline is Dutchman Creek just north of the Highway 172 bridge and Ashwaubenon Creek, which empties to the south of the bridge. Several streams empty into the lower bay along the west shore, though Duck Creek is by far the most significant.

Tributaries provide critical habitat for many fish species for migration, spawning, foraging, sheltering, and nurseries throughout different times of year. For example, Mahon Creek provides habitat for spottail shiner (*Notropis hudsonius*), rainbow darter (*Etheostoma caeruleum*), redside dace (*Clinostomus elongatus*), channel catfish (*Ictalurus punctatus*), and others. Northern pike (*Esox lucius*) utilize both small tributaries and roadside ditches along the west shore as migration corridors. Wequiock Creek within Point Sable is used by yellow perch as nursery habitat and by predatory fish (e.g., shortnose gar [*Lepisosteus platostomus*], bowfin [*Amia calva*]) for spawning habitat. Aquatic invertebrates, such as freshwater mussels, also use Tributary open water habitat (e.g., Wequiock Creek). (Summary information on fish usage of tributaries based on research conducted by UW-Green Bay students Eric Struck, David Lawrence, Angelena Koosmann, and Collin Moratz.)

We estimate that up to 20 km of quality tributary open water can be restored and maintained in the LGB&FR AOC, a realistic ideal condition for our assessment metric (Figure 2.70). We recommend a non-linear measure of tributary open water habitat, weighted by quality on a scale from 0 to 1. Converted to our standard scale, 20 km of high quality tributary open water habitat (quality = 1) would yield a maximum condition score of 10. Based mainly on expert opinion, the overall current condition for tributary open water habitat is quite low (=3).

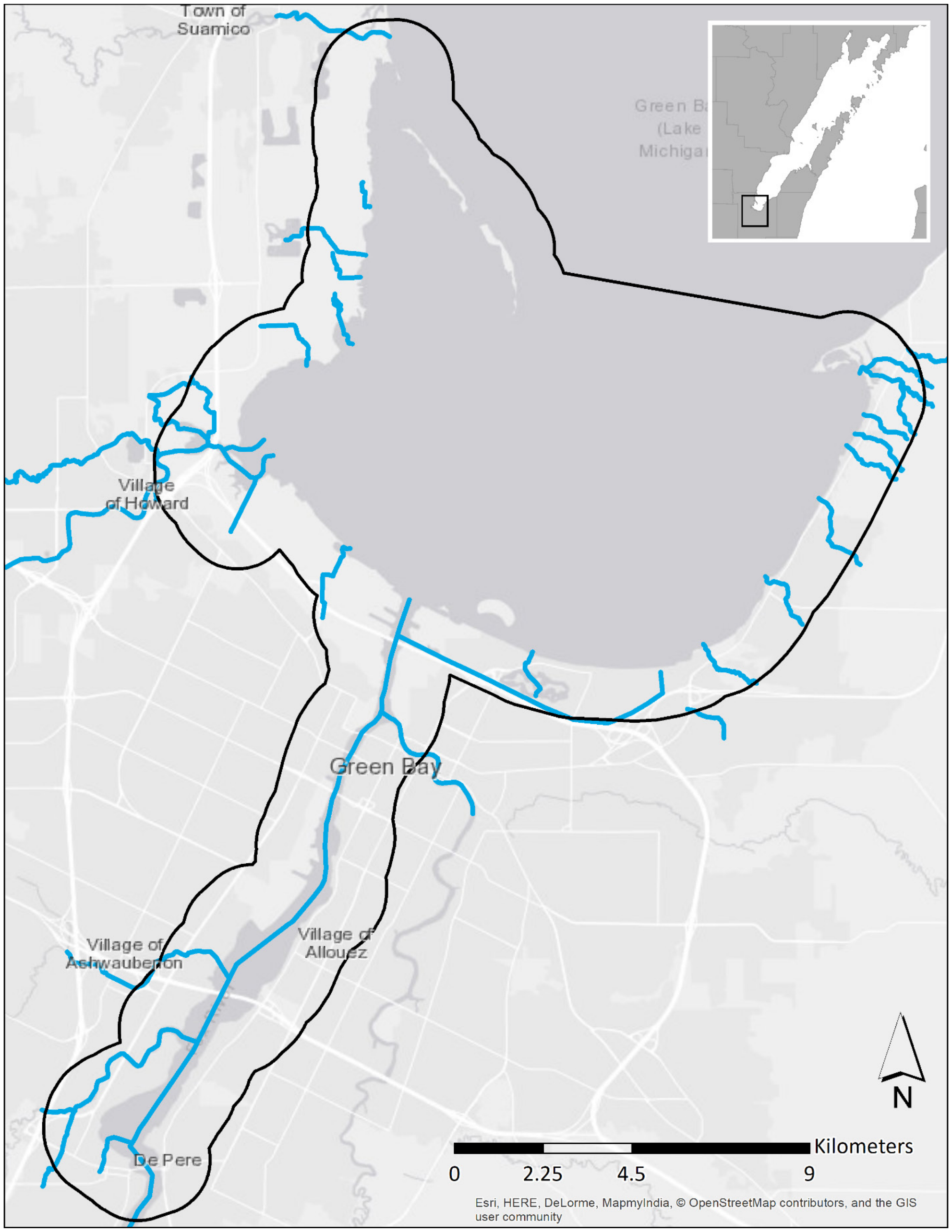


Figure 2.69. Tributaries in the Lower Green Bay and Fox River Area of Concern, including the Fox River. The black line shows the extent of the project study area. Basemap sources: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community. Map was created using ArcGIS 10.5 software (Environmental Systems Research Institute 2016).

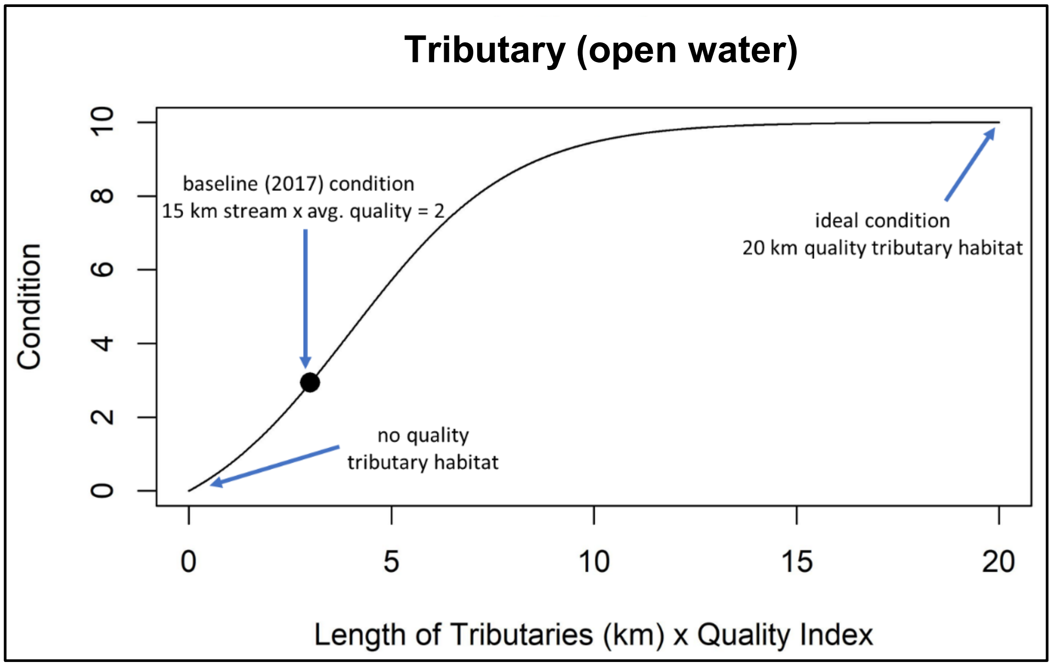


Figure 2.70. Tributary (open water) habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total length of quality tributary (open water) habitat (scaled from 0 [no quality tributary open water] to 20 [ideal tributary open water habitat, 20 km of quality tributary open water]), which is determined through field surveys, and the y-axis is the converted condition for a given area of quality tributary open water habitat, which ranges from poor condition (0) to good/ideal condition (10).

Tributary open water habitat at Ashwaubenon Creek. Photograph taken by Rebecca DeValk in July 2015.

Hardwood Swamp

Hardwood swamps are forested wetlands dominated by broadleaf, deciduous trees. Typically, hardwood swamp communities occur along lakes, streams, and especially in lowland areas that are poorly drained. Soils characteristic of this habitat are hydric, loamy sands. The most common canopy dominants of hardwood swamps in the LGB&FR AOC are green ash (*Fraxinus pennsylvanica*), red maple (*Acer rubrum*), eastern cottonwood (*Populus deltoides*), and swamp white oak (*Quercus bicolor*). A woody shrub layer is commonly present and often includes nannyberry (*Viburnum lentago*), shrubby dogwoods (*Cornus* spp.), and winterberry holly (*Ilex verticillata*). The herbaceous layer is often dominated by graminoid monocots, including fowl manna grass (*Glyceria striata*), eastern wild-rye (*Elymus virginicus*), and a large diversity of true sedge species (especially, *Carex cristatella*, *C. echinodes*, *C. intumescens*, *C. lupulina*, *C. radiata*, and *C. stipata*). Characteristc forbs of hardwood swamps include jewelweed (*Impatiens capensis*), sensitive fern (*Onoclea sensibilis*), blue skullcap (*Scutellaria lateriflora*), great blue lobelia (*Lobelia siphilitica*), calico aster (*Symphyotrichum lateriflorum*), and bedstraw species (*Galium* spp.). Hardwood swamp forests on the west shore of Green Bay that are dominated by red maple tend to have an herbaceous understory, including more acidophilic forbs, such as starflower (*Trientalis borealis*), Canada mayflower (*Maianthemum canadense*), spinulose wood fern (*Dryopteris carthusiana*), and several violet species (*Viola* spp.). Glossy buckthorn (*Frangula alnus*) and, to a lesser extent, common buckthorn (*Rhamnus cathartica*), are pestilential invasives of the shrub layer of AOC swamp forest communities where they eventually can completely shade out the herbaceous understory. Invasive honeysuckle species (*Lonicera × bella* and parent species of this hybrid, *L. morrowii* and *L. tartarica*) are also highly problematic invaders of the shrub tier of these wetland forest communities. Many amphibians and birds use hardwood swamps for breeding habitat, while dozens of migratory songbird species feed on insects and berries in these forests during spring and fall migration.

Hardwood swamp occurs throughout the LGB&FR AOC is the most abundant habitat type within the area, covering about 30% of the land. Locations of hardwood swamp include Point au Sable, St. Francis Tributary, University of Wisconsin-Green Bay campus, Bay Beach Wildlife Sanctuary West and East, Bay Beach Amusement Park Shoreline, Allouez Riverside Park, Jones Point, Nicolet Bank Forest, Voyager Park, Fox River Trail, Ashwaubenon Creek, Ashwaubomay Park, Dutchman Creek, Duck Creek, Fort Howard Wildlife Area, Barkhausen Waterfowl Preserve, Malchow/Olson Tract, Long Tail Beach, and Sensiba South. We estimate that up to 750 ha of quality hardwood swamp can be restored and maintained in the LGB&FR AOC, a realistic ideal condition for our assessment metric (Figure 2.71). We recommend a non-linear measure of hardwood swamp habitat, weighted by quality on a scale from 0 to 1. Converted to our standard scale, 750 ha of high-quality hardwood swamp habitat (quality = 1) would yield a maximum condition score of 10. Based mainly on our field surveys, the overall current condition for hardwood swamp habitat is mediocre (=5). Some of these areas in the LGB&FR AOC are in poor condition because they are invaded by honeysuckle and buckthorn in the understories. However, actively managing these invasive plants can greatly enhance this important habitat.

For more information on this habitat, visit the WDNR's Hardwood Swamp webpage: http://dnr.wi.gov/topic/EndangeredResources/Communities.asp?mode=detail&Code=CPFOR039WI.

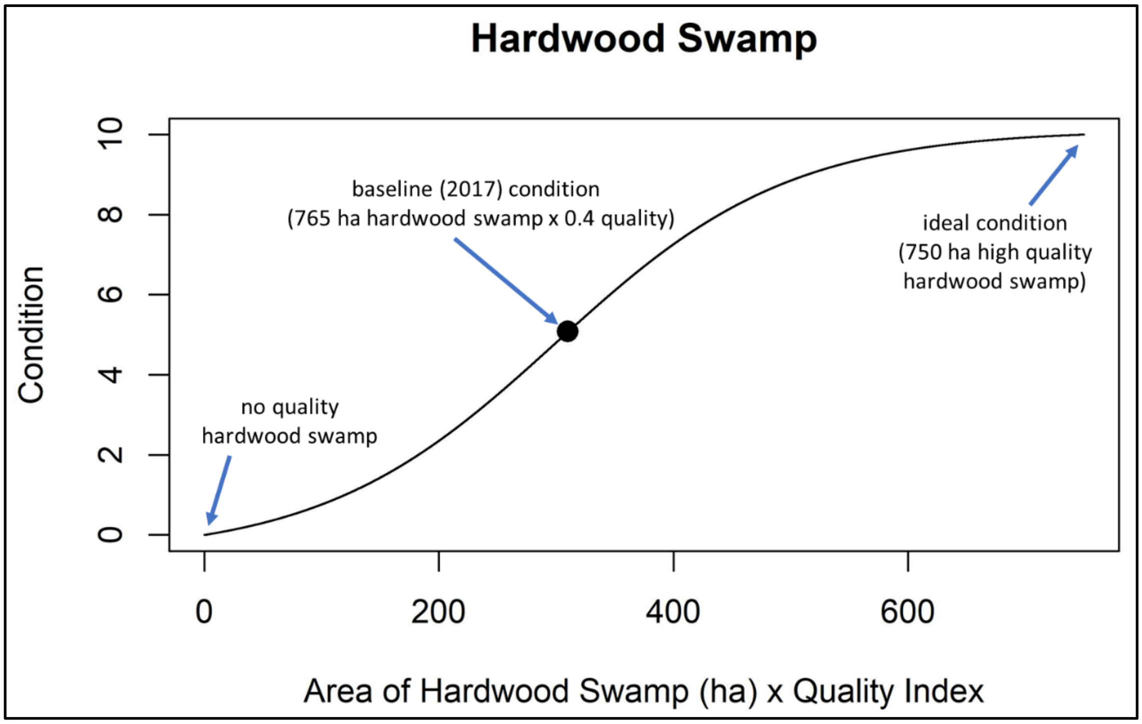


Figure 2.71. Hardwood swamp habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total area of quality hardwood swamp habitat (scaled from 0 [no quality hardwood swamp] to 750 [ideal hardwood habitat, 750 ha of quality hardwood swamp]), which is determined through field surveys, and the y-axis is the converted condition for a given area of quality hardwood swamp habitat, which ranges from poor condition (0) to good/ideal condition (10).

Hardwood swamp in the Cofrin Memorial Arboretum of the UW-Green Bay campus. Photograph taken by Robert Howe, July 2015.

Emergent Marsh (inland)

This community is an open wetland on circumneutral to alkaline, mineral soils around the margins of ponds and lakes, and dominated by emergent macrophytes. As is characteristic of emergent marshes, the soil is inundated with water for much of the year. Dominant native plant species include cattails (*Typha latifolia*, historically), bulrushes (*Schoenoplectus* spp.), bur-reeds (*Sparganium* spp.), arrowheads (*Sagittaria* spp.), true rushes (*Juncus* spp.), spikerush (*Eleocharis* spp.), and true sedges (*Carex* spp.). Covering about 7% of the LGB&FR AOC, inland emergent marshes are often invaded by common reed (*Phragmites australis* subsp. *australis*), hybrid cattail (*Typha* × *glauca*), reed canary grass (*Phalaris arundinacea*), and sometimes also by narrow-leaved cattail (*Typha angustifolia*). Native plant diversity, including both emergent and submergent vegetation, creates a healthy ecosystem. The plants provide oxygen and filter the water by absorbing certain nutrients and preventing algal blooms. Inland emergent marshes also provide safe spawning habitat for fish and nesting habitat for birds and amphibians.

Inland emergent marsh habitat can be found throughout the LGB&FR AOC in such localities as Point au Sable, Barina Parkway, UW-Green Bay campus, Bay Beach Wildlife Sanctuary, Allouez Riverside Park, Abbey Pond, Ashwaubomay Park, Duck Creek Estuary, Fort Howard Wildlife Area, Barkhausen Waterfowl Preserve, the Malchow/Olson Tract, and Sensiba South. We estimate that up to 150 ha of quality inland emergent marsh can be restored and maintained in the LGB&FR AOC, a realistic ideal condition for our assessment metric (Figure 2.72). We recommend a non-linear measure of emergent marsh (inland) habitat, weighted by quality on a scale from 0 to 1. Converted to our standard scale, 150 ha of high-quality emergent marsh (inland) habitat (quality = 1) would yield a maximum condition score of 10. Based mainly on our field surveys, the overall current condition for emergent marsh (inland) habitat is somewhat low (=4). Most of these areas in the LGB&FR AOC are in poor condition, being heavily invaded by Phragmites, reed canary grass, or other non-native plants.

For more information on this habitat, visit the WDNR's Emergent Marsh webpage: http://dnr.wi.gov/topic/EndangeredResources/Communities.asp?mode=detail&Code=CPHER056WI.

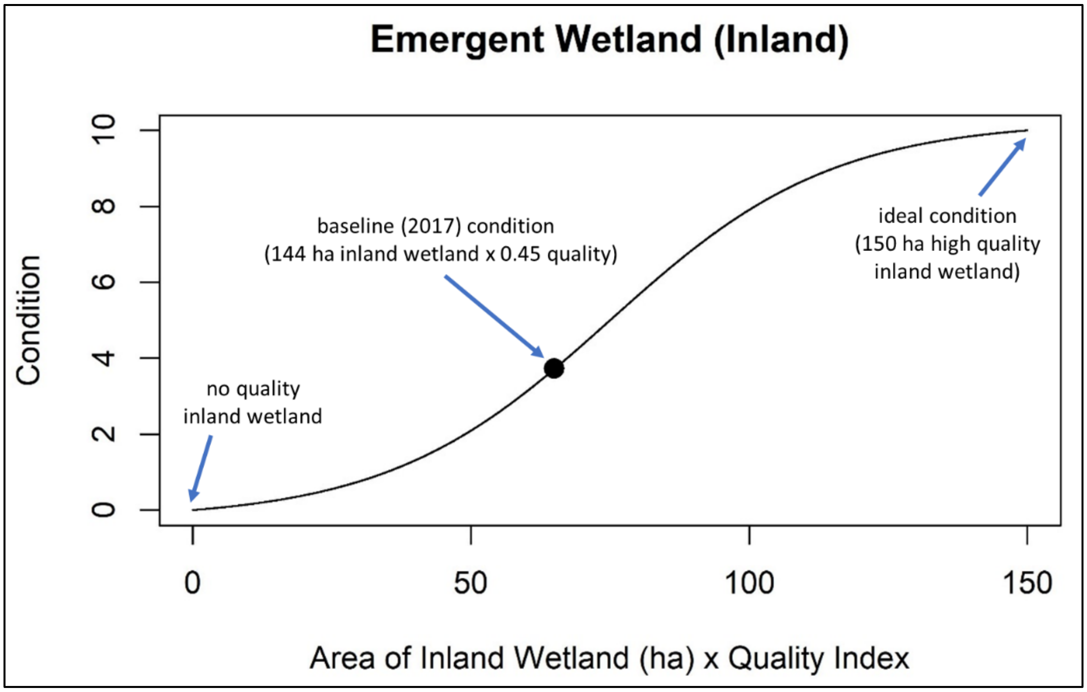


Figure 2.72. Emergent marsh (inland) habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total area of quality emergent marsh (inland) habitat (scaled from 0 [no quality emergent marsh inland] to 150 [ideal emergent marsh inland, 150 ha of quality emergent marsh inland]), which is determined through field surveys, and the y-axis is the converted condition for a given area of quality emergent marsh (inland) habitat, which ranges from poor condition (0) to good/ideal condition (10).

Emergent marsh (inland) along Highway 57 near Bay Beach Wildlife Sanctuary. Photograph taken by Robert Howe, July 2015.

Open Water (inland)

Including small retention ponds, there are several inland bodies of open water in the LGB&FR AOC, though there are five areas with a significant amount of inland open water that provide important habitat for fish and wildlife, including: 1) Point Sable lagoon in the Town of Scott, 2) Bay Beach Wildlife Sanctuary ponds in Green Bay, 3) west shore suburban ponds in Suamico, 4) pond just south of Hurlbut Street in Green Bay, and 5) Abbey Pond in De Pere. Habitats surrounding open water (inland) may include emergent marsh (inland), shrub carr, and hardwood swamp.

Many different bird species utilize inland open water (or adjacent habitats) for breeding, such as Pied-billed Grebe (*Podilymbus podiceps*), Black-crowned Night-Heron (*Nycticorax nycticorax*), Purple Martin (*Progne subis*), Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*), and Red-winged Blackbird (*Agelaius phoeniceus*), as well as stopover habitat for migratory waterfowl (e.g., Northern Shoveler (*Spatula clypeata*), Bufflehead (*Bucephala albeola*). Inland water bodies are particularly important to marsh-obligate breeding birds during low water level years in the bay of Green Bay when few deep emergent marshes are available. Many different fish species and odonates (dragonflies + damselflies) also use inland ponds, including odonate species, such as eastern forktail (*Ischnura verticalis*) and twelve-spotted skimmer (*Libellula pulchella*).

We estimate that up to 60 ha of quality inland open waters can be restored and maintained in the LGB&FR AOC, a realistic ideal condition for our assessment metric (Figure 2.73). We recommend a non-linear measure of inland open water habitat, weighted by quality on a scale from 0 to 1. Converted to our standard scale, 60 ha of high quality inland open water habitat (quality = 1) would yield a maximum condition score of 10. Based on expert opinion, the overall current condition for inland open water is fairly low (=3).

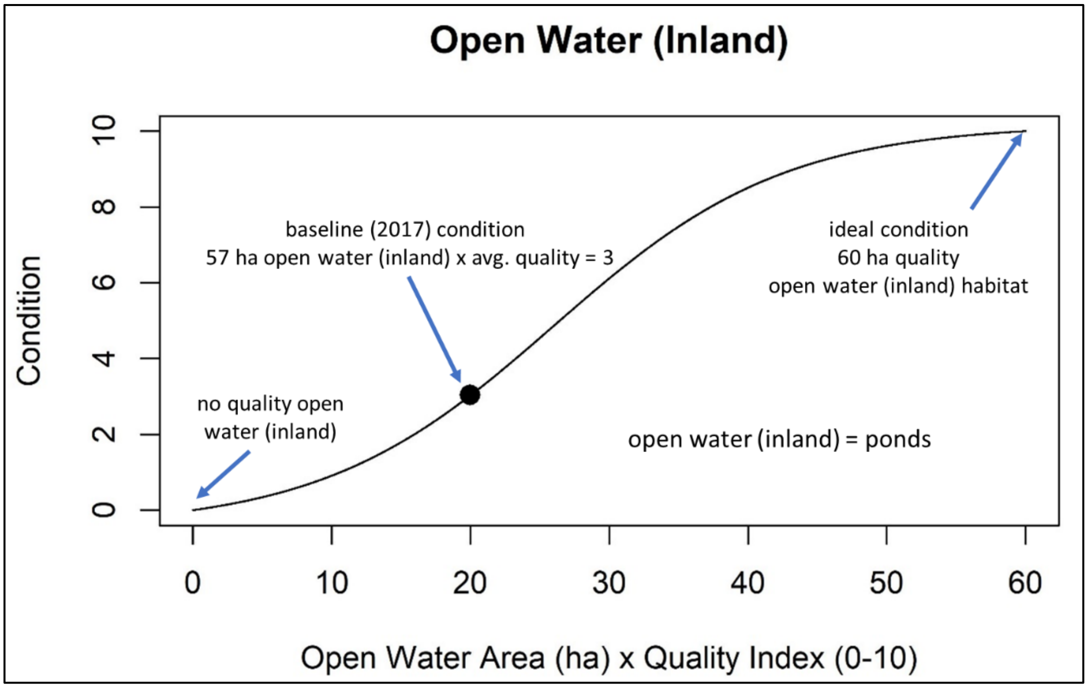


Figure 2.73. Open water (inland) habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total area of open water (inland) habitat (scaled from 0 [no quality inland open water] to 60 [ideal inland open water, 60 ha of inland open water]), which is determined through field surveys, and the y-axis is the converted condition for a given area of quality open water (inland) habitat, which ranges from poor condition (0) to good/ideal condition (10).

Open water (inland) west of the Pulliam Plant along Hurlbut Street. Photograph taken by Erin Giese in December 2016.

Southern Dry Mesic Forest

This upland forest type in the LGB&FR AOC is characterized by an oak-dominated canopy of both red oak (*Quercus rubra*) and white oak (*Quercus alba*). American basswood (*Tilia americana*), sugar maple (*Acer saccharum*), and shagbark hickory (*Carya ovata*) typically also contribute to the canopy. Black cherry (*Prunus serotina*) is characteristically present in the subcanopy. Southern dry mesic forests occur on well-drained, loamy soils formed in till, and cover about 1% of the habitat in the LGB&FR AOC.

In the LGB&FR AOC, southern dry mesic forests are found on the University of Wisconsin-Green Bay campus, Optimist Point, Ashwaubomay Park, Dutchman Creek, and near Longtail Beach Road. We estimate that up to 50 ha of quality southern dry mesic forest can be restored and maintained in the LGB&FR AOC, a realistic ideal condition for our assessment metric (Figure 2.74). We recommend a slightly non-linear measure of southern dry mesic forest habitat, weighted by quality on a scale from 0 to 1. Converted to our standard scale, 50 ha of high quality southern dry mesic forest habitat (quality = 1) would yield a maximum condition score of 10. Based mainly on our field surveys, the overall current condition for southern dry mesic forest habitat is mediocre (=5).

For more information on this habitat, visit the WDNR's Southern Dry Mesic Forest webpage: http://dnr.wi.gov/topic/EndangeredResources/Communities.asp?mode=detail&Code=CTFOR014WI.

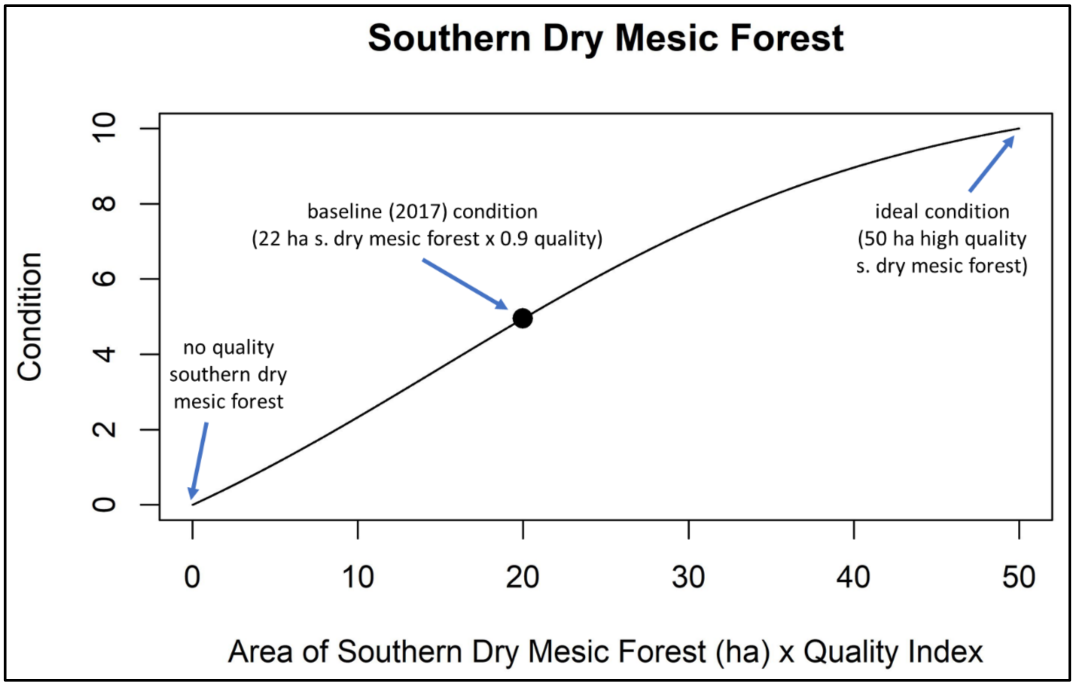


Figure 2.74. Southern dry mesic forest habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total area of quality southern dry mesic forest (scaled from 0 [no quality southern dry mesic forest] to 50 [ideal southern dry mesic forest, 50 ha of quality forest]), which is determined through field surveys, and the y-axis is the converted condition for a given area of quality southern dry mesic forest habitat, which ranges from poor condition (0) to good/ideal condition (10).

Southern dry mesic forest along Highway 57 near Bay Beach Wildlife Sanctuary. Photograph taken by Robert Howe in July 2015.

Northern Mesic Forest

Northern mesic forests occur on loamy soils of glacial till plains and cover about 2% of the LGB&FR AOC. Canopy dominants of mesic forests within the LGB&FR AOC are sugar maple

(*Acer saccharum*), basswood (*Tilia americana*), green ash (*Fraxinus pennsylvanica*), and black walnut (*Juglans nigra*). Younger secondary forests may also include eastern cottonwood (*Populus deltoides*) and trembling aspen (*Populus tremuloides*) as canopy dominants. American elm (*Ulmus americana*), alternate-leaf dogwood (*Cornus alternifolia*), and hop-hornbeam (*Ostrya virginiana*) may contribute to a woody subcanopy tier. Frost grape (*Vitis riparia*) and Virginia creeper (*Parthenocissus quinquefolia*) are conspicuous as woody climbers. Common shrubs include American highbush cranberry (*Viburnum trilobum*), red elderberry (*Sambucus racemosa*), and currant/gooseberry species (*Ribes* spp., especially *R. americanum* and *R. cynosbati*). The herbaceous understory is diverse and includes many showy spring ephemerals, such as bloodroot (*Sanguinaria canadensis*), wild ginger (*Asarum canadense*), Jack-in-the-pulpit (*Arisaema triphyllum*), red baneberry (*Actaea rubra*), and large-flowered trillium (*Trillium grandiflorum*). Sedges (*Carex* spp.), ferns (including *Deparia arcostichoides* and *Athyrium filix-femina*), and an array of other forbs (including *Circaea canadensis*, *Smilax ecirrhata*, and *Solidago flexicaulis*) are typically also present.

Invasive species of LGB&FR AOC northern mesic forests consist of both shrubs and herbs. Common buckthorn (*Rhamnus cathartica*) is the most problematic invasive woody species in many areas, but its success as a weed is closely matched by showy bush honeysuckle (*Lonicera × bella* and parent species, *L. morrowii* and *L. tartarica*), European highbush cranberry (*Viburnum opulus*), glossy buckthorn (*Frangula alnus*), and autumn olive (*Elaeagnus umbellata*). Garlic mustard (*Alliaria petiolata*) and dame's rocket (*Hesperis matronalis*) are herbaceous invasive species of these forest communities that may be difficult to eradicate once they become established.

Northern mesic forests have four different stages of growth: late seral, mid seral, early seral, and young seral. Late seral forests, also known as old growth forests, typically have the highest species diversity of these four stages. Old growth forests also have the greatest range of tree size and age, greatest architectural complexity, and ample woody debris at many stages of decomposition. In contrast, mid-seral forests are characteristically composed of trees of more similar size and age, with trunks of relatively smaller diameter (28-38$^+$ cm dbh). Older and larger trees may be present as widely scattered individuals, and more mature mid seral forests will include saplings as the woody understory differentiates. Trees of yet younger age and smaller bole size (12.7-28 cm dbh) that exist in stands of uniform age (or sometimes two age classes) characterize early seral forests. Early seral forest floors have little accumulation of woody debris. High competition inhibits new saplings from growing. Young seral forests, the least mature of the four seral stages, grow from clear-cutting or a high disturbance event. Woody debris may be largely absent or, if present, may be either highly decayed or fresh, depending on the type of disturbance. Young seral forests are composed of trees with boles of up to 12.7 cm dbh and have low species diversity. The highest quality northern mesic forests of the LGB&FR AOC are at the (late) mid-seral stage of maturity.

The LGB&FR AOC is closely positioned to the Tension Zone, which roughly delimits the northern limit of several plant species that are distributed in southern Wisconsin. Species composition of canopy trees of mesic forests in the AOC partly reflects this boundary, with shagbark hickory (*Carya ovata*) and black walnut (*Juglans nigra*) confined to mesic forests on the east shore of Green Bay. These two walnut family (Juglandaceae) species are characteristic elements of southern mesic forests (particularly *C. ovata*, which reaches its northern limit of distribution in Wisconsin near the Door County line), and their presence imparts a distinctively 'southern' aspect to mesic forests on the east shore.

This habitat can be found in the AOC at Point au Sable, Wequiock Creek, University of Wisconsin-Green Bay campus, Red Smith Woods, near St. Francis Park, St. Norbert campus, Cottage Grove Complex, and Malchow/Olson Tract. We estimate that up to 75 ha of quality northern mesic forest can be restored and maintained in the LGB&FR AOC, a realistic ideal condition for our assessment metric (Figure 2.75). We recommend a non-linear measure of northern mesic forest habitat, weighted by quality on a scale from 0 to 1. Converted to our standard scale, 75 ha of high quality northern mesic forest habitat (quality = 1) would yield a maximum condition score of 10. Based mainly on our field surveys, the overall current condition for northern mesic forest habitat is somewhat low (=4) largely due to woody understory invasive plants, such as buckthorn.

For more information on this habitat, visit the WDNR's Northern Mesic Forest webpage: http://dnr.wi.gov/topic/EndangeredResources/Communities.asp?mode=detail&Code=CTFOR034WI.

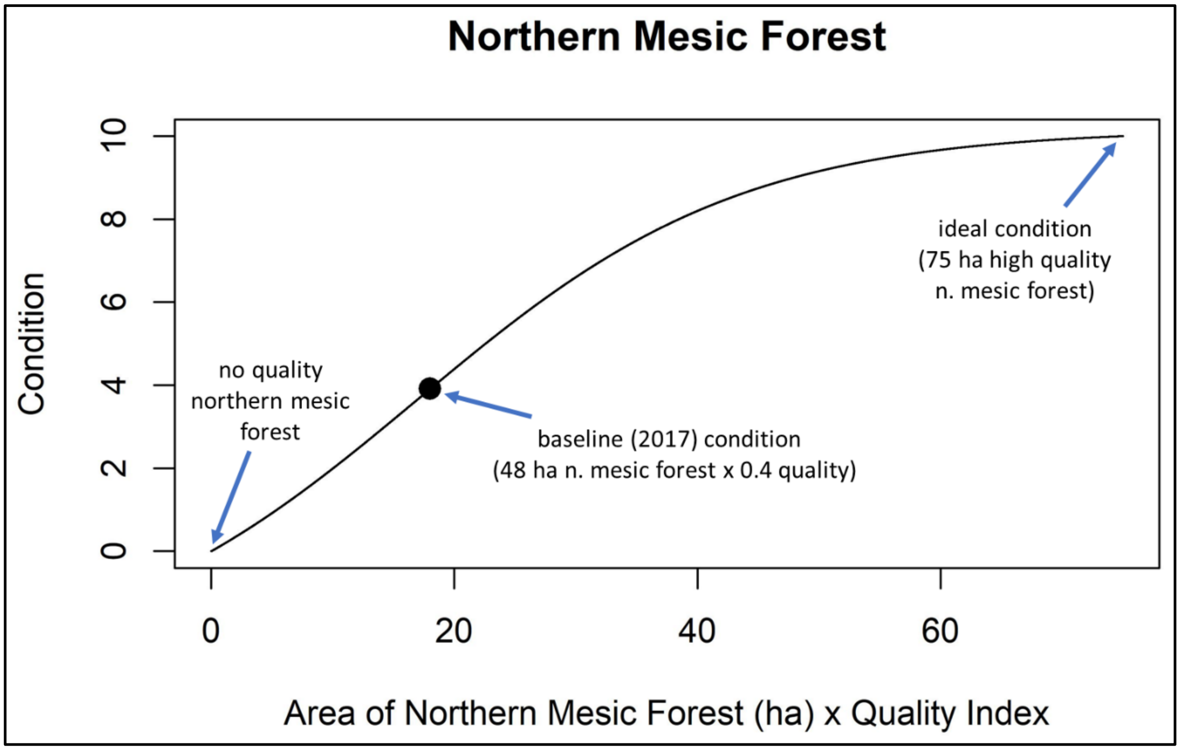


Figure 2.75. Northern mesic forest habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total area of quality northern mesic forest (scaled from 0 [no quality northern mesic forest] to 75 [ideal northern mesic forest, 75 ha of quality forest]), which is determined through field surveys, and the y-axis is the converted condition for a given area of quality northern mesic forest habitat, which ranges from poor condition (0) to good/ideal condition (10).

Northern mesic forest east of Point Sable along Wequiock Creek corridor. Photograph taken by Robert Howe in July 2015.

Surrogate Grassland Restored

Historically, grasslands were widespread but now only remain in small pockets of habitat. Farming and urban development have contributed to the decrease in savannah habitat. As a result, tallgrass prairies are now the most diminished and threatened plant communities in the Midwest. Surrogate grasslands now offer a similar prairie environment for plants and animals. In the LGB&FR AOC, less than 1% of the land is categorized as restored surrogate grassland. This category of surrogate grassland includes fields planted with natural prairie grasses. The dominant grass species include Indian grass (*Sorghastrum nutans*), big bluestem (*Andropogon gerardii*), and switch grass (*Panicum virgatum*). However, these restored grasslands still fall short of the rich species diversity of the original prairies.

This habitat is found at the University of Wisconsin-Green Bay campus (Keith White Prairie + UWGB Oak Savanna), and Fox River Trail within the LGB&FR AOC. We estimate that up to 20 ha of quality restored surrogate grassland can be restored and maintained in the LGB&FR AOC, a realistic ideal condition for our assessment metric (Figure 2.76). We recommend a non-linear measure of restored surrogate grassland habitat, weighted by quality on a scale from 0 to 1. Converted to our standard scale, 20 ha of high-quality restored surrogate grassland habitat (quality = 1) would yield a maximum condition score of 10. Based mainly on our field surveys, the overall current condition for surrogate grassland (restored) habitat is mediocre (=5).

For more information on this habitat, visit the WDNR's Surrogate Grassland webpage: http://dnr.wi.gov/topic/EndangeredResources/Communities.asp?mode=detail&Code=OSURRGRASS.

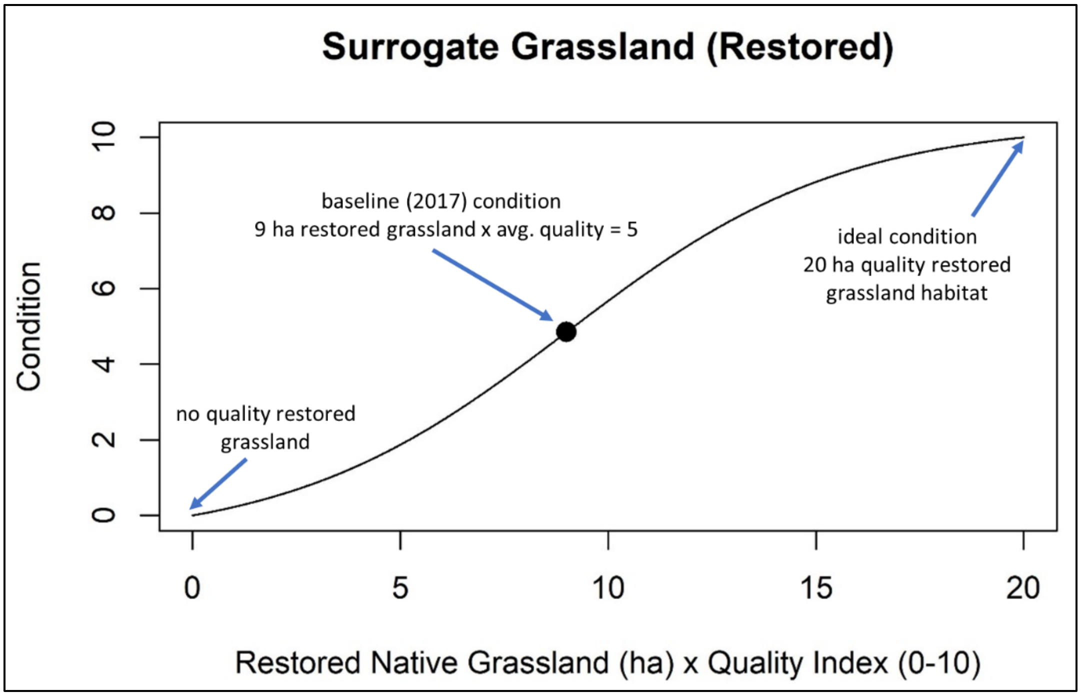


Figure 2.76. Surrogate grassland (restored) habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total area of quality restored surrogate grassland (scaled from 0 [no quality restored surrogate grassland] to 20 [ideal restored surrogate grassland, 20 ha of quality restored surrogate grassland]), which is determined through field surveys, and the y-axis is the converted condition for a given area of quality restored surrogate grassland habitat, which ranges from poor condition (0) to good/ideal condition (10).

Surrogate grassland restored, Keith White Prairie (UW-Green Bay campus). Photograph taken by Kathryn Corio in August 2016.

Emergent Marsh (roadside)

This plant community consists of species characteristic of emergent marshes growing in wet, roadside ditches that often hold standing water until mid-summer. The encroachment of woody species into such areas is typically suppressed by mowing. Native dominants, when present, include cattails (*Typha latifolia*), bulrushes (*Schoenoplectus pungens* and *S. tabernaemontani*), arrowheads (*Sagittaria latifolia*), northern water-plantain (*Alisma triviale*), spikerush (*Eleocharis* spp.), true rushes (*Juncus* spp.), and true sedges (*Carex* spp., especially *C. bebbii* and *C. vulpinoidea*). Covering about 1% of the LGB&FR AOC, roadside emergent marshes are often invaded by common reed (*Phragmites australis* subsp. *australis*), reed canary grass (*Phalaris arundinacea*), hybrid cattail (*Typha* × *glauca*), and narrow-leaved cattail (*Typha angustifolia*). Native plant diversity, including both emergent and submergent vegetation, creates a healthy ecosystem. Despite human disturbance, some marsh birds, such as Red-winged Blackbird (*Ixobrychus exilis*), use this habitat for nesting, and northern pike (*Esox lucius*) use these riparian corridors to travel to inland spawning habitats (e.g., west shore).

Emergent marsh (roadside) can be found near Bay Beach, Ashwaubenon Creek, Dutchman Creek, the University of Wisconsin-Green Bay Campus, the railroad complex on the West side, Duck Creek, and along interstates and highways. Especially noteworthy examples occur along Lineville Road. We estimate that up to 25 ha of quality restored emergent marsh (roadside) can be restored and maintained in the LGB&FR AOC, a realistic ideal condition for our assessment metric (Figure 2.77). We recommend a non-linear measure of roadside emergent marsh habitat, weighted by quality on a scale from 0 to 1. Converted to our standard scale, 25 ha of high quality roadside emergent marsh habitat (quality = 1) would yield a maximum condition score of 10. Based mainly on our field surveys, the overall current condition for roadside emergent marsh habitat is somewhat poor (=4) due to heavy invasions of Phragmites and the hybrid cattail.

For more information on this habitat, visit the WDNR's Emergent Marsh webpage: http://dnr.wi.gov/topic/EndangeredResources/Communities.asp?mode=detail&Code=CPHER056WI.

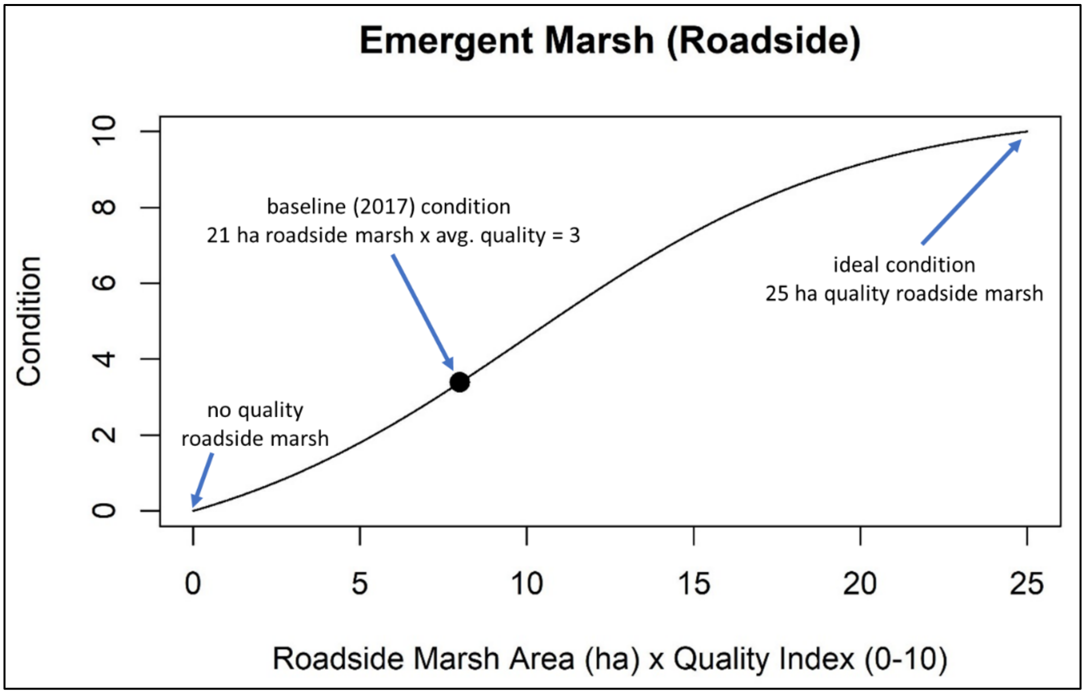


Figure 2.77. Emergent marsh (roadside) habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total area of quality emergent marsh (roadside) habitat (scaled from 0 [no quality emergent marsh roadside] to 25 [ideal emergent marsh roadside, 25 ha of quality emergent marsh roadside]), which is determined through field surveys, and the y-axis is the converted condition for a given area of quality emergent marsh (roadside) habitat, which ranges from poor condition (0) to good/ideal condition (10).

Emergent marsh (roadside) of *Phragmites australis*. Photograph taken by Rebecca DeValk in July 2015.

Other Forest

Early successional forests in the LGB&FR AOC are typically dominated by trembling aspen (*Populus tremuloides*), green ash (*Fraxinus pennsylvanica*), and eastern cottonwood (*Populus deltoides*), with wetter sites sometimes also including box elder (*Acer negundo*), peach-leaved willow (*Salix amygdaloides*), and crack willow (*Salix* × *fragilis*) as dominants. These forests typically have an open canopy and an understory that is often dominated by invasive species. Pine plantations are also considered as 'other forests.' Such forests do not readily fit into any widely recognized plant community type and thus are placed in 'other forests.' Accounting for 7% of the LGB&FR AOC habitat, these forests are the four largest habitat type.

Other forest are found in the LGB&FR AOC at Point au Sable, St. Francis Tributary, Barina Parkway, University of Wisconsin-Green Bay campus, Bay Beach Wildlife Sanctuary, Frigo Bridge Inlet, Fox River Trail, Allouez Riverside Park, St. Norbert campus, Voyager Park, Ashwaubenon Creek, Wisconsin Public Service of Green Bay complex, Ken Euers Nature Area, Duck Creek, Cottage Grove Complex, Peter's Marsh, Barkhausen Waterfowl Preserve, and Sensiba South. We estimate that up to 200 ha of quality other forest can be restored and maintained in the LGB&FR AOC, a realistic ideal condition for our assessment metric (Figure 2.78). We recommend a non-linear measure of other forest habitat, weighted by quality on a scale from 0 to 1. Converted to our standard scale, 200 ha of high-quality other forest habitat (quality = 1) would yield a maximum condition score of 10. Based mainly on our field surveys, the overall current condition for other forest habitat is mediocre (=5).

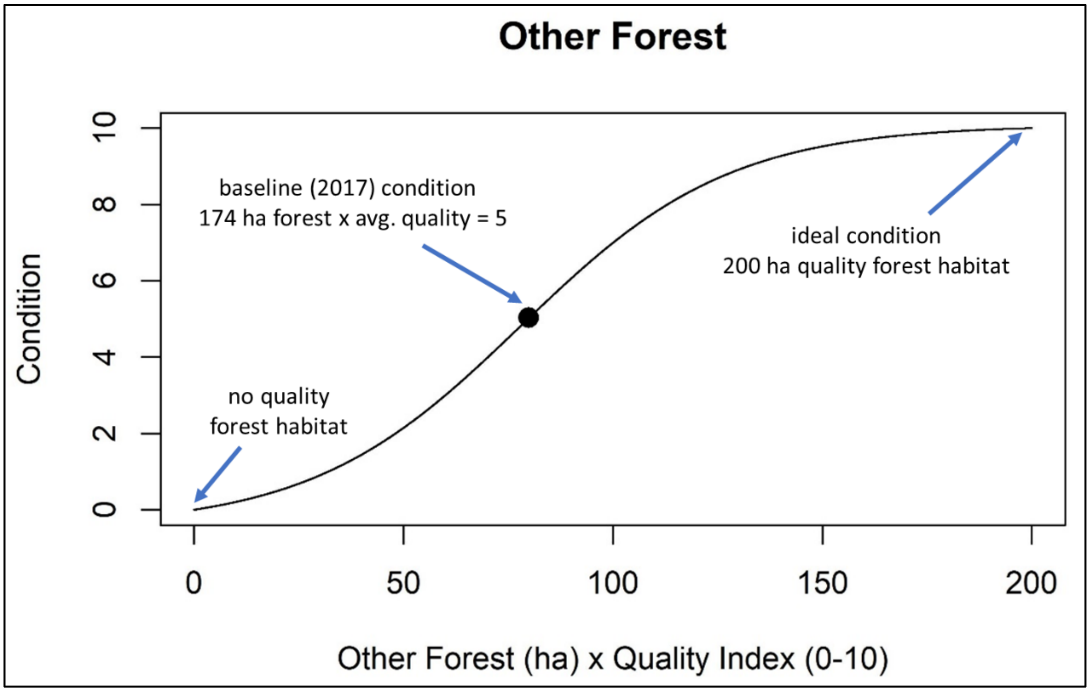


Figure 2.78. Other forest habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total area of quality other forest (scaled from 0 [no quality other forest] to 200 [ideal other forest, 200 ha of quality forest]), which is determined through field surveys, and the y-axis is the converted condition for a given area of quality other forest habitat, which ranges from poor condition (0) to good/ideal condition (10).

Other forest along Nicolet Drive on the east shore. Photograph taken by Robert Howe in July 2015.

Surrogate Grassland (old field, upland shrubs)

Historically, grasslands were widespread in Wisconsin but now only remain in small pockets of habitat. Farming and urban development have contributed to the decrease of savannah habitat. As a result, tallgrass prairies are now the most diminished and threatened plant communities in the Midwest. Surrogate grasslands offer a similar prairie-like, high-light environment for plants and animals. However, it is highly unlikely that any old-field surrogate grasslands within the LGB&FR AOC originally had prairie vegetation. In the LGB&FR AOC, about 6% of the land is categorized as old field/upland shrub surrogate grassland.

This category of surrogate grassland includes hayfields, pastures, parks, mowed fields and fields dominated by shrubs. Although such areas are typically dominated by non-native and often highly invasive species, the very rare, highest quality examples of this ecosystem include dominant grass species such as Indian grass (*Sorghastrum nutans*) and switch grass (*Panicum virgatum*).

Within the LGB&FR AOC, old field/upland shrub surrogate grassland occurs at Point au Sable, Wequiock Creek, Barina Parkway, University of Wisconsin-Green Bay campus, Bay Beach Wildlife Sanctuary, Fox River Trail, Abbey Pond, Ashwaubomay Park, Ken Euers Nature Area, Duck Creek, and Sensiba South. We estimate that up to 200 ha of quality old field / surrogate grassland can be restored and maintained in the LGB&FR AOC, a realistic ideal condition for our assessment metric (Figure 2.79). We recommend a non-linear measure of old field / surrogate grassland habitat, weighted by quality on a scale from 0 to 1. Converted to our standard scale, 20 ha of high-quality old field / surrogate grassland habitat (quality = 1) would yield a maximum condition score of 10. Based mainly on our field surveys, the overall current condition for surrogate grassland (old field) habitat is mediocre (=5).

For more information on this habitat, visit the WDNR's Surrogate Grassland webpage: http://dnr.wi.gov/topic/EndangeredResources/Communities.asp?mode=detail&Code=OSURRGRASS.

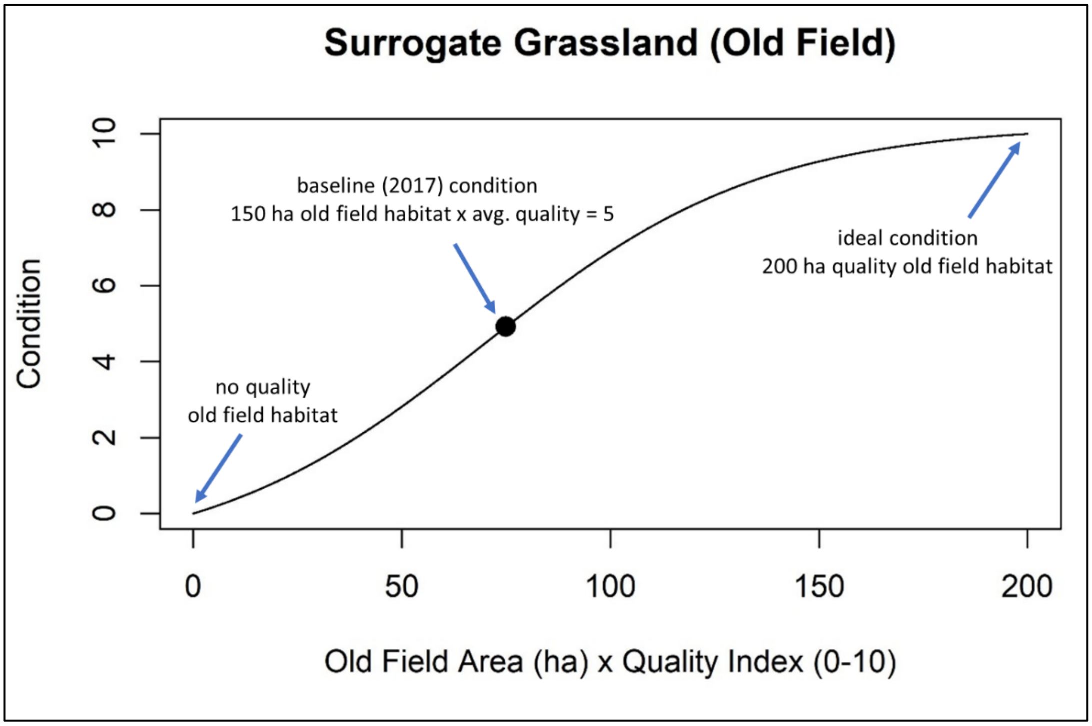


Figure 2.79. Surrogate grassland (old field) habitat assessment for the Lower Green Bay and Fox River Area of Concern. The x-axis represents the total area of quality old field / surrogate grassland (scaled from 0 [no quality old field / surrogate grassland] to 200 [ideal old field / surrogate grassland, 200 ha of quality old field / surrogate grassland]), which is determined through field surveys, and the y-axis is the converted condition for a given area of quality old field / surrogate grassland habitat, which ranges from poor condition (0) to good/ideal condition (10).

Surrogate grassland (old field, upland shrubs) at Abbey Pond in De Pere. Photograph taken by Rebecca DeValk in July 2015.

Great Lakes Barrens

Great Lakes barrens are a savanna-like community type developed on well-drained, sandy soils derived from ancient lake dunes. Pines (*Pinus* spp.) dominate the open to sparse canopy, sometimes completely, and the understory includes low, ericaceous shrubs. It is one of the least common plant community types in Wisconsin and is globally imperiled. Great Lakes barrens are a very rare plant community type in the LGB&FR AOC, occurring on just a small portion of the Malchow/Olson Tract. Here, the open canopy (~30% cover) is dominated by northern red oak (*Quercus rubra*), red maple (*Acer rubrum*), and white pine (*Pinus strobus*). The understory dominated by black huckleberry (*Gaylussacia baccata*) and bracken fern (*Pteridium aquilinum* var. *latiusculum*), with occasional northern oak sedge (*Carex deflexa* var. *deflexa*) and Pennsylvania sedge (*Carex pensylvanica*).

For more information on this habitat, visit the WDNR's Great Lakes Barrens webpage: http://dnr.wi.gov/topic/EndangeredResources/Communities.asp?mode=detail&Code=CTSAV007WI. Note that this habitat type was *not* included in the LGB&FR AOC F&W Habitat Assessment Tool because it was not likely a historically dominant habitat in the LGB&FR AOC and currently occurs as just a single, small patch in the LGB&FR AOC. It was also not found during the 2015 habitat mapping effort and is therefore not delineated in the habitat GIS shapefile. Because of its rarity, Great Lakes barren is not a priority habitat, is excluded from the fish and wildlife habitat assessment process, and thus does not have a conversion curve.

Great Lakes barrens habitat at the Malchow/Olson Tract. Photograph taken by James Horn in 2016.

Conservation Project Catalogue

We compiled a total of 254 conservation projects, including both current and historical conservation projects and one potential project not yet funded. This list of projects is by no means complete, however. There are still additional projects missing from this list, but this catalogue is a first attempt at compiling as many conservation projects from the LGB&FR AOC as possible. The most common project types included in the catalogue are monitoring or research projects (168), followed by habitat restoration projects (46), invasive species management (10), and management plans (9; Table 2.17). The least common project types currently included in the catalogue are land protection or conservation, land management, water resources management, land use planning and modeling, and species restoration (Table 2.17). Conservation projects pertain to a variety of different taxa and topics, including projects related to fish (73), plants (72), birds (66), water quality (62), invertebrates (39), mammals (22), soil (19), herptiles (reptile or amphibian; 16), and fungi (8). However, it should be noted that a project was classified according to all taxa (e.g., fish, mammals) or topics (e.g., water quality) to which it applied.

Table 2.17. Total number of projects based on each project type or focus (e.g., management plan) for those that have been added to the LGB&FR AOC Conservation Project Catalogue.

Project Type	Total
Habitat Restoration	46
Invasive Species Management	10
Land Management	5
Land Protection or Conservation	8
Land Use Planning and Modeling	2
Management Plan	9
Monitoring or Research	168
Species Restoration	2
Water Resource Management	5

Projects organized by a variety of different agencies (federal or state), non-profit organizations, tribes, universities, cities/towns, Brown County, environmental consulting/ engineering firms, and others are included in this catalogue, including the following (listed alphabetically):

- Anderson Engineering of Minnesota LLC
- Applied Ecological Services
- Bay-Lake Regional Planning Commission
- Brown County
- City of De Pere
- City of Green Bay
- Ducks Unlimited
- Fox River/Green Bay Natural Resource Trustee Council
- Fox Wolf Watershed Alliance
- Glacierland RC&D
- Great Lakes Coastal Wetland Monitoring Program, which represents multiple agencies and universities, especially the University of Minnesota-Duluth, Central Michigan University, and U.S. Environmental Protection Agency.
- Green Bay Southwest High School
- Interfluve, Inc.
- Lawrence University
- Michigan State University
- National Oceanic and Atmospheric Administration
- NEW Water
- Nicholls State University
- Northeast Wisconsin Land Trust
- Oneida Nation
- The Nature Conservancy
- U.S. Army Corps of Engineers
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service
- U.S. Geological Survey
- University of Wisconsin-Green Bay
- University of Wisconsin-Madison
- University of Wisconsin-Milwaukee
- University of Wisconsin-Sea Grant
- University of Wisconsin-Superior
- Village of Allouez
- Wisconsin Department of Natural Resources
- Wisconsin Society for Ornithology

Stakeholder Engagement

We held 17 LGB&FR AOC stakeholder meetings between June 2015 and December 2017 (Table 2.18), three of which included presentations on overall project status updates. Fourteen meetings were interactive, in which we generated discussions with stakeholders and asked for specific feedback and information on various aspects of the project, including:

a) Compiling lists of current or historical LGB&FR AOC projects,

b) Gaining historical information on LGB&FR AOC fish and wildlife habitat and populations,
c) Identifying critical fish and wildlife habitats, populations, and areas of interest (i.e., "priority areas),
d) Evaluating the current condition or status of priority habitats and priority species/species groups,
e) Reviewing our LGB&FR AOC Fish and Wildlife Assessment Process and Tools, and
f) Reviewing proposed BUI removal targets for fish and wildlife habitat and populations.

Throughout this project, stakeholders have made significant contributions both by providing much needed information on fish and wildlife habitats and populations and by carefully and critically thinking through our proposed assessment process, recommended projects, and BUI removal targets. Many of these stakeholders are active conservationists, environmentalists, scientists, biologists, managers, retirees, and engaged citizens who regularly work with fish and wildlife in this AOC and are therefore vital to the success of removing both of these fish and wildlife BUIs and the LGB&FR AOC as a whole. Their engagement and comments throughout this process are much appreciated and have helped make this project successful.

Table 2.18. List of 17 LGB&FR AOC stakeholder meetings that took place between June 2015 and December 2017.

Date	Location	Type	Audience	Purpose
23 Jun 2015	UW-Green Bay	Interactive	Local fish and wildlife experts	Introduction to the project; compile existing information on fish and wildlife from attendees
17 Dec 2015	WDNR	Presentation	AOC technical stakeholders	Status update on the project
06 Jan 2016	UW-Green Bay	Interactive	Fish experts	Get feedback on identifying priority fish species and potential projects
13 Jan 2016	UW-Green Bay	Interactive	Local expert Thomas Erdman	Gain historical information on the LGB&FR AOC and identify potential projects
19 Jan 2016	UW-Green Bay	Interactive	Local expert Thomas Erdman	Gain historical information on the LGB&FR AOC and identify potential projects
22 Jan 2016	UW-Green Bay	Interactive	Local expert Thomas Erdman	Gain historical information on the LGB&FR AOC and identify potential projects
19 Apr 2016	UW-Green Bay	Interactive	Green Bay Conservation Partners	Introduction to the project; compile existing information on fish and wildlife from attendees
30 Jun 2016	WDNR	Presentation	AOC technical stakeholders	Status update on the project
16 Dec 2016	UW-Green Bay	Interactive	Local fish and wildlife experts	Status update on the project; review draft lists of AOC priority areas and fish and wildlife species/species groups
27 Jan 2017	WDNR	Presentation	AOC technical stakeholders	Status update on the project; review draft assessment tools

25 Apr 2017	UW-Green Bay	Interactive	Green Bay Conservation Partners	Get feedback on the AOC Fish and Wildlife Habitat Assessment Tool and brainstorm potential habitat restoration projects
24 May 2017	UW-Green Bay	Interactive	Local fish and wildlife experts	Review the AOC Fish and Wildlife Habitat and Populations Assessment Tools, discuss BUI removal targets, and brainstorm potential projects
15 Jun 2017	UW-Green Bay	Interactive	Local fish experts	Identify priority fish groups, evaluate their current condition, and brainstorm potential projects
03 Aug 2017	WDNR	Interactive	AOC technical stakeholders	Get feedback on the AOC Fish and Wildlife Habitat and Populations Assessment Tools and setting BUI removal targets
28 Sep 2017	UW-Milwaukee	Interactive	WDNR, USEPA, & USFWS staff	Overview of AOC fish and wildlife assessment process and get general feedback
01 Nov 2017	WDNR	Interactive	WDNR, USEPA, & USFWS staff	Overview of AOC fish and wildlife assessment process, discuss BUI removal targets and management action/project list
06 Dec 2017	UW-Green Bay	Interactive	Local fish and wildlife experts	Review the AOC Fish and Wildlife Habitat and Populations Assessment Tools, discuss BUI removal targets and potential projects

Fish & Wildlife Assessment + BUI Removal Process

We framed the outcome of our six-step BUI removal strategy in two analytical MS Excel worksheets that calculate overall current condition (on a scale of 0-10) for the fish and wildlife habitats and fish and wildlife populations BUIs, respectively (Tables 1.2 and 1.3). These worksheets show the ranks used to assign weights for each element (habitat or species/species group), state and global ranking (NatureServe Global Conservation Status Ranks 2017) used by the Wisconsin Department of Natural Resources Natural Heritage Program, and overall baseline condition assigned during the course of this project. A built-in formula calculates a weighted average of condition scores, yielding the overall current condition score for each BUI. This number can be used to track progress toward the two BUI removal targets.

The MS Excel worksheets conveniently allow users to explore different scenarios for reaching each BUI removal target. In other words, changing the condition score for one or more elements (habitats or species/species groups) automatically results in a change in the overall condition score. If many elements are included in the calculations, then the impacts of each change in condition are diluted; at the other extreme, limiting the analysis to just a few habitats or species/species groups risks neglect of habitats or species/species groups that are critical components of the LGB&FR AOC ecosystem. The selection of 18 habitats and 22 species/species groups assures that effective conservation actions are needed for multiple but not necessarily all elements of the system. At the same time, these numbers are sufficient to incorporate all or nearly all of the habitat and population targets identified by the original RAP documents (Wisconsin Department of Natural Resources 2016a).

Based on results of stakeholder meetings and discussions with WDNR biologists, we established a BUI removal target of 6.0 (on a scale of 0-10) for fish and wildlife habitats and 6.5 for fish and wildlife populations (species/species groups). The weighted average baseline condition for habitats (3.60) was considerably lower than the baseline condition for species/species groups (4.65), so by consensus we set the habitat BUI removal target lower. In both cases, significant future improvements will be needed to elevate the overall condition scores to the BUI removal targets. It is possible to reach these targets, however, with minimal or even no progress on the extremely difficult habitat elements such as Green Bay open water and Fox River open water. Of course, any progress in improving water quality in this system will have multiple impacts on improving the overall LGB&FR AOC condition since the baseline condition is currently very low (in both cases, condition = 3 on a scale of 0-10).

DISCUSSION

Guidelines for removing BUIs in Great Lakes AOCs have been published by the International Joint Commission (IJC; International Joint Commission 1991) and USEPA (United States Policy Committee 2001). According to these documents, the removal of the fish and wildlife habitat BUI is justified "when the amount and quality of physical, chemical, and biological habitat required to meet fish and wildlife management goals have been achieved and protected." The IJC/USEPA guidelines (United States Policy Committee 2001) recommend removing the fish and wildlife population BUI when "environmental conditions support healthy, self-sustaining communities of desired fish and wildlife at predetermined levels of abundance that would be expected from the amount and quality of suitable physical, chemical and biological habitat present." BUI removal efforts must ensure that fish and wildlife objectives for AOCs are consistent with Great Lakes ecosystem objectives and Great Lakes Fishery Commission fish community goals (e.g., Eshenroder et al. 1995). In the absence of community structure data, populations will be considered restored when fish and wildlife bioassays confirm no significant toxicity from water column or sediment contaminants. The 2001 USEPA BUI removal principles further recommend locally derived goals, supported by data and rationale. The document strongly emphasizes that site-specific monitoring using measurable indicators is integral to the BUI removal justification (United States Policy Committee 2001).

Specific BUI removal targets for the LGB&FR AOC were first articulated in the 1988 RAP and subsequent updates (Wisconsin Department of Natural Resources 2016a). Our recommended framework builds on these by establishing more tangible endpoints and by improving quantitative metrics for assessing progress toward the BUI removal goals. We have attempted to integrate the previous targets into our 18 priority habitats and 22 species/species groups (Table 1.2 and 1.3). If our quantitative BUI removal targets are reached, one can argue strongly that the earlier RAP BUI removal targets likewise will have been reached. One possible exception is the RAP target involving levels of contaminants (particularly total PCBs) in fish tissues (Wisconsin Department of Natural Resources 2016a). Environmental contaminants are explicitly addressed by other BUIs in the LGB&FR AOC, but they are mentioned in the fish and wildlife population BUI because of their importance for fish populations, fish-eating birds, and other wildlife. Our BUI removal framework includes no specific assessment of toxic contaminants in fish and wildlife tissues. However, we have included sensitivity to toxins as one of our weighting criteria for species and species groups. We assigned higher priority weights to seven groups of fish-eating wildlife (colonial waterbirds, coastal wetland mustelids, breeding coastal birds, Fox

River fish, freshwater unionid mussels, wetland terns, and wintering Bald Eagles) because of their sensitivity to environmental toxins. The 1991 BUI removal guidelines (International Joint Commission 1991) state that wildlife toxin bioassays are needed “in the absence of community structure data.” Our framework includes several relevant measures of community structure, so we contend that bioassays are not needed as quantitative targets for the fish and wildlife populations BUI. This argument is strengthened by the fact that three other BUIs in the LGB&FR AOC (Wisconsin Department of Natural Resources 2016a) deal directly with toxic contaminants: 1) fish tumors or other deformities, 2) bird or animal deformities or reproductive problems, and 3) restrictions on fish and wildlife consumption.

Other scientists have sought to improve the objectivity of AOC BUI removal targets (Michigan Department of Environmental Quality 2014). Criteria for the removal of the fish and wildlife population BUI in the White River AOC in Michigan were based on a quantitative index of biotic integrity (IBI) for fish populations modified from Uzarski et al. (2005). Standardized fish samples at AOC and reference sites were used to determine whether trends at AOC sites represented regional or local changes (Janetski and Ruetz III 2015). Removing the fish and wildlife habitat BUI was the goal of five specific activities, including restoration of municipally and privately-owned shoreline areas, coastal marsh monitoring, and restoration of critical sites in the littoral zone.

At Canada’s Bay of Quinte AOC, Macecek and Grabas (2011) described IBI metrics for fish, breeding birds, and amphibians of coastal wetlands, submerged aquatic vegetation, and aquatic macroinvertebrates, in addition to a water quality index developed by Chow-Fraser (2006). Like other BUI removal teams, they sampled coastal wetland areas outside the Bay of Quinte AOC to provide reference values for the IBIs and water quality metrics. More recently, Bowlby and Hoyle (2017) used principal components analysis to compare nearshore fish communities in Canada’s Hamilton Harbour and Toronto Harbour AOCs with fish communities in nine unimpaired embayments in Lake Ontario. In general, our framework includes an even broader range of aquatic and coastal biotic elements (habitats and species/species groups) than previous strategies for removing fish and wildlife-related BUIs. Another major difference in our framework is the lack of dependence on specific reference sites. Green Bay exhibits a strong natural trophic gradient from south to north (Sager and Richman 1991, Brazner 1997, Klump et al. 2009), so habitats and species assemblages in the middle and upper bay are not directly comparable to those in the LGB&FR AOC (e.g., Gnass Giese et al. 2018). Similar embayment ecosystems in the Great Lakes, like Lake Huron’s Saginaw Bay and western Lake Erie, also are not suitable as reference areas because, like Green Bay, these systems are ecologically impaired. Our assessment framework uses independently derived objectives for population measures (e.g., number of Piping Plover nests, number of wintering Bald Eagles) and multispecies metrics like the index of ecological condition (Howe et al. 2007, Gnass Giese et al. 2015), which do not depend on comparisons with specific reference areas. The overall BUI removal targets (e.g., 6.0 vs. 6.5 on a scale from 0-10) ultimately are established and endorsed by stakeholder engagement and discussion, taking into account economic, sociological, and other important considerations, in addition to ecological criteria. Individual metrics for habitats and populations provide transparent, objective mechanisms for achieving the consensus-derived BUI removal targets. A key feature of this framework is that multiple paths may lead to the successful removal of these two BUIs.

Regardless of the specific metrics used to assess current condition (e.g., IBIs, IECs, or simple geographic measurements or area or shoreline), some degree of informed subjectivity is unavoidable in setting and pursuing BUI removal goals. Which species or habitat types are assessed? What are the relevant attributes of habitats and species/species groups in unimpaired areas? What is an appropriate metric for quantifying biotic condition? How does the current (baseline) condition fit into the broader context of worst possible to best possible conditions? The importance of a quantitative framework is that these subjective decisions become transparent and debatable. For example, we propose a target (desired future condition) of 6.0 for the removal of the "degradation of fish and wildlife habitat" BUI. Critics who disagree with this target must submit a specific alternative from which they can frame their arguments. These arguments must specifically convince decision-makers that the proposed value is too low or too high. We concede that our proposed values indeed might need to be revised based on improved information or better reasoning. Like our current scheme, these new values will be both quantitative and transparent, ready to stand the tests of further scrutiny and study. Without a quantitative and transparent assessment framework, however, such debates would not be possible.

Even in unimpaired condition, nearshore areas of lower Green Bay and the Fox River corridor undergo dramatic changes in response to changing water levels, storms, and other factors, including human activities (Gnass Giese et al. 2018). Hence, the desired future condition of fish and wildlife habitats and species/species groups must acknowledge some degree of natural variability in assessment metrics. Such variability can be acknowledged by defining a range of condition scores that qualify as acceptable BUI removal targets during a prescribed window of time. For example, authors of the White Lake AOC Delisting Report (Michigan Department of Environmental Quality 2015) justified the removal of the fish and wildlife population BUI when the fish IBI score ranged within 9.3% of the target value for three consecutive years. Although we do not yet have the data to apply credible confidence intervals, we eventually will need to identify a range of conditions to ensure that our BUI removal targets are sustained for an adequate period. Our proposed improvements (on a 0-10 scale) between current condition and the BUI removal targets are 2.40 for habitats (3.60 → 6.00) and 1.85 for species/species groups (4.65 → 6.50). The natural range of variation should not exceed these increments if we hope to clearly detect improvements. Habitats and wildlife species/species groups in the lower Green Bay and Fox River ecosystem will need to be monitored and assessed regularly to ensure that the BUI removal thresholds are met on the long term. Without explicit quantitative metrics and subsequent assessment and monitoring, the range of natural variation will be impossible to interpret meaningfully.

In summary, our proposed framework for setting BUI removal targets and tracking progress in the LGB&FR AOC provides a more transparent and objective approach than previous, mostly subjective BUI removal strategies. The ambitious but attainable goals described here are quantitative, flexible, and ecologically broad. They include many (18) habitat types and (22) species/species groups and therefore create multiple paths to success. Future work will be needed to refine and implement the details, including field monitoring protocols and analysis of natural environmental variability. Nevertheless, the recommended methods provide a starting point for systematic restoration and rehabilitation of fish and wildlife habitats and fish and wildlife populations in this important, but complex, AOC. We hope that this framework also will be applicable to other Great Lakes AOCs as well as other large-scale, ecologically impaired landscapes.

Data Gaps

The BUI removal framework that we have described is information intensive so, not surprisingly, filling information gaps is an important step in successfully implementing the process. Better information about all of the habitats and species/species groups will improve the effectiveness of management actions in achieving the goals of BUI removal. Several information gaps, however, are particularly critical.

The status of freshwater unionid mussels in lower Green Bay and the Fox River has never been well documented, but they certainly were present and perhaps were once a major component of the nearshore and riparian benthic environment. The enormous growth of dreissenid mussels, also filter feeders, suggests that freshwater mussels (including both native unionids as well as fingernail clams in the family Sphaeriidae) indeed have had an important functional role in the LGB&FR AOC ecosystem. Field studies to locate remnant mussel beds in the lower bay should be a high priority. Weinzinger's (2017) study of mussels in tributaries may help encourage a long-range plan to re-establish local populations at sites where substrate and water quality might favor success of these long-lived invertebrates.

Invertebrates, in general, are poorly documented in the LGB&FR AOC even though we have identified three population groups (coastal wetland aquatic macroinvertebrates, coastal terrestrial macroinvertebrates, and stream macroinvertebrates) as priorities for the "degradation of fish and wildlife populations" BUI. These species are important ecosystem elements because they provide a prey base for many other groups (e.g., shoreline fish, anurans, tributary fish, Fox River fish, bats, and migratory shorebirds) and some species are of conservation significant in their own right (e.g., the state endangered hairy-necked tiger beetle, *Cicindela hirticollis rhodensis*). Some information is available from the Great Lakes Coastal Wetland Monitoring Program (Uzarski et al. 2017) and the 2016 field surveys of odonates by Willson Gaul, but systematic surveys of invertebrate species in all three zones (nearshore, wetlands, and tributaries) are badly needed. These studies should aim not only to better characterize the LGB&FR AOC fauna, but also be designed to help guide the development of multi-species assessment metrics.

Significant information gaps also exist for two other aquatic taxa, turtles and coastal wetland mustelids. Our recommended status for both groups is based on very little information, so improved field information will help establish a better overall condition assessment for the LGB&FR AOC. Additionally, these studies will help identify specific conservation actions and localities that may contribute substantially to the BUI removal objectives.

Although information used in this report for fish numbers and fish breeding/spawning habitat is very limited, ongoing research by Patrick Forsythe, Steve Hogler, Tammie Paoli, and many other fish biologists will help fill important information gaps during the next five years. Like our studies of resident and migratory birds, anurans, and bats, existing information needs to be analyzed and combined with other data sources, but information for these groups is much less severe than it is for the other groups mentioned above.

Next Steps

Our recommended path to removing the two fish and wildlife related BUIs is straightforward: *implement conservation actions that improve the status of one or more priority fish and wildlife habitats or populations*. The BUI removal targets can be met in multiple ways, specifically by implementing projects that improve some combination of 18 habitats or 22 species/species groups. In practice, the most effective restoration strategies will be those aimed at highly weighted elements whose baseline condition scores are low and whose conditions are most amenable to improvement. These highly weighted elements (habitats or populations) provide opportunities for the biggest "bang for the buck" in terms of conservation investment.

While some conservation actions are much more effective than others, no single conservation action will be sufficient to justify the removal of either BUI. An increase in condition of 5.2 units (of 10) for each of the seven top-ranked species/species groups will elevate the overall fish and wildlife population score to the BUI removal target of 6.5. For habitats, the most parsimonious path to BUI removal (overall score of 6.0) is to increase the condition scores of each of the five top-ranked habitats by 6.95. No matter how great the effort (i.e., to the maximum condition score of 10), improvements in fewer than seven species/species groups or fewer than five habitat types cannot mathematically achieve the recommended BUI targets. At the other extreme, a minimum increase of 1.85 is needed for all species/species groups in order to reach the populations BUI target. For habitats, the minimum across-the-board increase needed to reach the target is 2.40. In other words, an increase in condition score of less than 1.85 for all 22 species/species groups or an increase of less than 2.40 for all 18 habitat categories is insufficient to reach either of the recommended targets.

Recommended Projects

Specific guidance for improving the condition of the LGB&FR AOC (and ultimately reaching the recommended BUI removal targets) can be found in our narratives for fish and wildlife populations and habitats (above) and priority areas (Appendix 10). This information can be distilled even further into a table of specific project recommendations, organized according to the general objectives and populations and habitats that they will benefit (Appendix 9). This is not an exhaustive list, and it surely can be improved as new information is revealed. We hope that new versions will be produced by stakeholders. Some projects on the list (e.g., 2. Construct and maintain island structures for nesting colonial waterbirds, especially endangered terns) already are being implemented. Others are expensive and will take many years to fulfill (e.g., 17. Enforce TMDL regulations in Fox River watershed). Nevertheless, implementation of a significant number of these management actions will move the overall LGB&FR AOC condition steadfastly toward the two fish and wildlife-related BUI removal targets.

Some of the most effective management actions are relatively inexpensive. Virtually all Great Lakes beach habitat in the LGB&FR AOC is located on public land or on private lands with conservation-sympathetic landowners. Designation of these beaches as sensitive areas, removal of invasive species, enhancing the shoreline with dead wood, and removal of dreissenid mussel shells will significantly improve the condition of these areas. Good examples of hardwood swamp remain in several places on both the east and west shores of lower Green Bay; improving the condition of some of these areas will require invasive species control and perhaps planting native understory shrubs, but relatively modest improvements in management will elevate the overall condition of these already good-quality habitats.

Factors that make the LGB&FR AOC dynamic and productive also make it vulnerable to change, so progress toward the BUI removal target must be coupled with the recognition that maintaining populations and habitats at the desired condition will present new challenges. Even today, threats from new invasive species, urban/suburban land development, pollution, and other factors must be countered by active stewardship of desirable populations and habitats. This will not change when condition of the LGB&FR AOC reaches the BUI removal targets; if anything, the stewardship challenges will be greater.

In conclusion, we present paths toward removing the two fish and wildlife BUIs that are achievable but challenging. Reaching (and maintaining) the proposed targets will require a significant commitment of new projects in addition to sustained commitment to a conservation infrastructure for maintaining the condition of habitats and populations at desired levels. The stakes we suggest are high. The Lower Green Bay and Fox River estuary is one of the most productive ecosystems in the Great Lakes, supporting a rich diversity of habitats and fish and wildlife populations that have potential to play an even greater role in the economy and cultural identity of northeastern Wisconsin.

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APPENDICES

Appendix 1: Bird Survey Methodology (2015-2017)

Appendix 1.1: Surveys in Open Wetlands (2015-2016)

Field Work

We determined that limited information has been collected on wetland birds in terms of using standardized methods, particularly in many small and inland (or disconnected) open wetlands that are dominated by herbaceous plants in the LGB&FR AOC. This information gap is largely due to the fact that the Great Lakes Coastal Wetland Monitoring Program (CWMP, 2011-2017, Uzarski et al. 2017; http://www.greatlakeswetlands.org) only samples Great Lakes coastal wetlands at least 4 ha in size and that are connected and influenced by a Great Lake (e.g., seiche). Thus, many small, inland, or partially forested wetlands that are still dominated by herbaceous plants within the LGB&FR AOC (e.g., along the Fox River, lower Green Bay) have not been recently surveyed for wetland birds. Thus, Erin Giese and a student assistant, Stephanie Beilke, scouted and identified 13 locations (Figure 1, Appendix 1.1) within the LGB&FR AOC that trained UW-Green Bay students surveyed for wetland birds in the summer of 2015. Two additional points were added along the west shore of the lower Bay and sampled in 2016. Some of these wetland locations were also sampled for anurans (n = 7). Once a point count location was established, Giese and a student assistant filled out a Site Description form (one per location), which documents the location's name and geospatial coordinates, safe parking areas, dominant plants, compass bearing (used for repeatability of anuran and wetland bird surveys), property information, and any other helpful notes (Figure 2, Appendix 1.1).

Wetland birds were sampled using the same, widely accepted protocol used for the CWMP, namely a 15-minute, unlimited-distance point count, in which trained observers recorded all birds seen or heard regardless of how far away an individual was calling from the observer (Great Lakes Coastal Wetlands Consortium 2014, pp. 132-136, Uzarski et al. 2017). During the first five minutes of the 15-minute count, an observer listened passively to all birds calling or singing and recorded all species and individuals; during the middle five minutes, a broadcast of bird songs/calls was played to elicit vocalizations from secretive marsh-nesting species (e.g., rails); and finally during the last five minutes, an observer passively listened to all birds vocalizing. All species, number of individuals, and the minute and distance an individual was first detected were recorded on the point count form (Figure 3, Appendix 1.1), though for ten focal species (e.g., rails, bitterns) every minute a focal species vocalized was also recorded. Point count locations were visited twice in the summer (late May through early July 2015; or late May through late June 2016), once in the early morning hours and once in the evening, in order to detect different bird species based on their activity. Visits were separated by at least 15 days. Surveys were conducted during relatively good weather conditions with minimal wind and precipitation. Basic weather information (e.g., cloud cover, wind), air and standing water temperatures, start time, compass bearing, noise level, and geospatial coordinates of point count locations were collected at each survey.

Six UW-Green Bay students (advanced undergraduates or graduates) were trained to conduct wetland bird surveys on 23 and 26 March 2015. Another graduate student was trained to conduct wetland bird surveys on 7 March, 28 March, and 15 April 2016. This student conducted point counts at the two points added in 2016. For safety purposes, surveys were conducted by teams of two students, one conducting the survey itself and the other collecting weather and geospatial information and helping with navigation and operating the broadcast of bird calls. Students who conducted the bird surveys were also required to pass the required, rigorous certification test, as is done for the CWMP (see QAPP section "Personnel, Special Training Requirements, or Certifications").

Data Entry

After the field season, two UW-Green Bay students double entered bird data into a MS Excel spreadsheet created by Giese that employed data validation techniques to minimize data entry error; the two entries were subsequently compared to produce a final, high quality data set (see QAPP "Data Management" for more details on data entry). Accompanying metadata were later added.

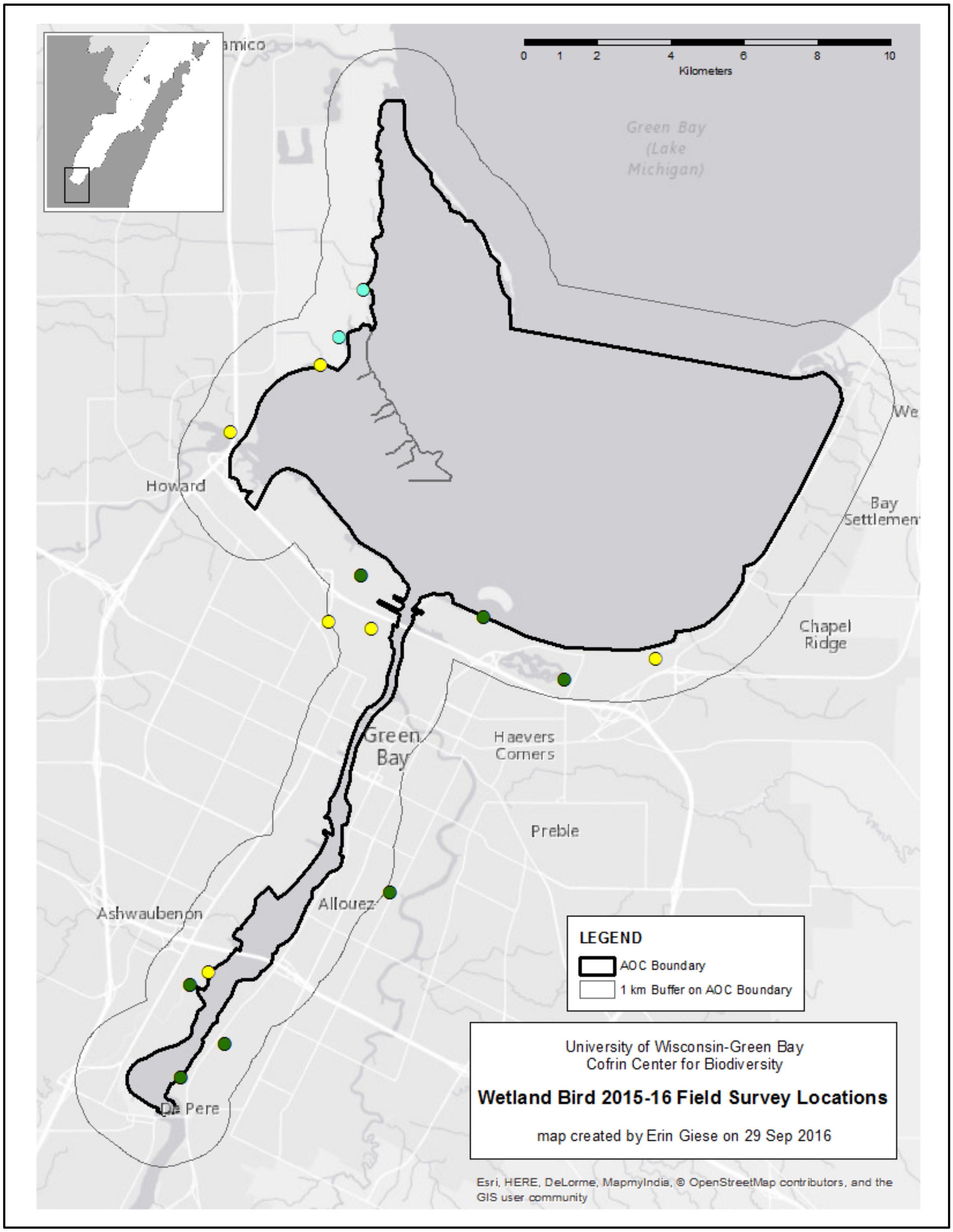
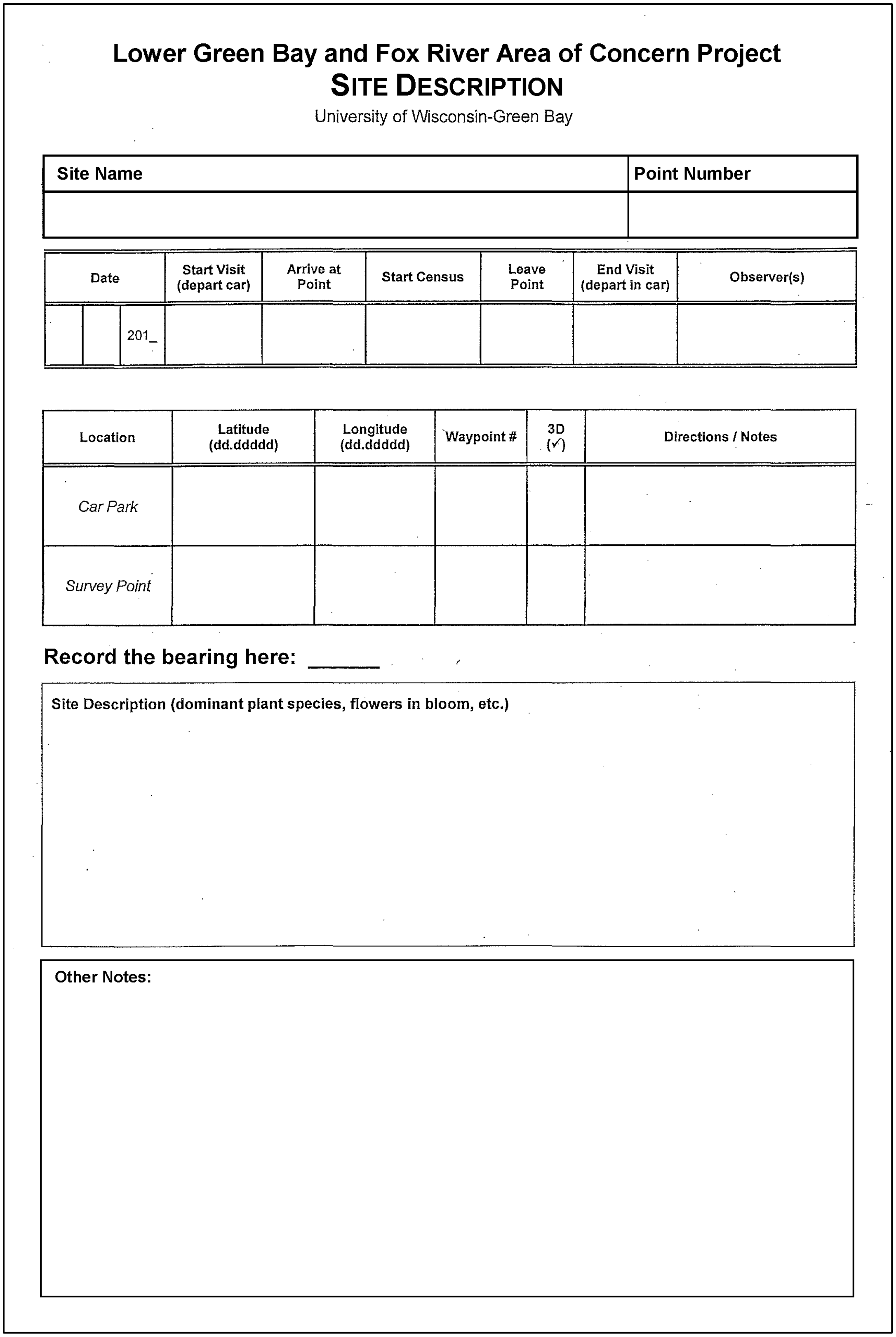


Figure 1. Point count locations (n = 15) positioned in open wetlands primarily dominated by herbaceous plants that were surveyed for wetland birds in the summer of 2015 or 2016. They are located within 1 km of shoreline at Lake Michigan/Green Bay high water level of 177.2 m AMSL in the Lower Green Bay and Fox River Area of Concern in Wisconsin. Points surveyed for both wetland birds and anurans are shown as green dots (n = 7); yellow dots indicate wetland bird-only points surveyed in 2015 (n = 6); light teal dots indicate wetland bird-only points surveyed in 2016 (n = 2). Note that one point in the village of Allouez and one point along the western portion and mouth of the Fox River are located just slightly outside this 1 km buffer (~100-200 m). Basemap sources: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community. Map created in ArcGIS 10.3.1 (Environmental Systems Research Institute 2015).



Lower Green Bay and Fox River Area of Concern Project

SITE DESCRIPTION

University of Wisconsin-Green Bay

Site Name	**Point Number**

Date			**Start Visit (depart car)**	**Arrive at Point**	**Start Census**	**Leave Point**	**End Visit (depart in car)**	**Observer(s)**
		201_						

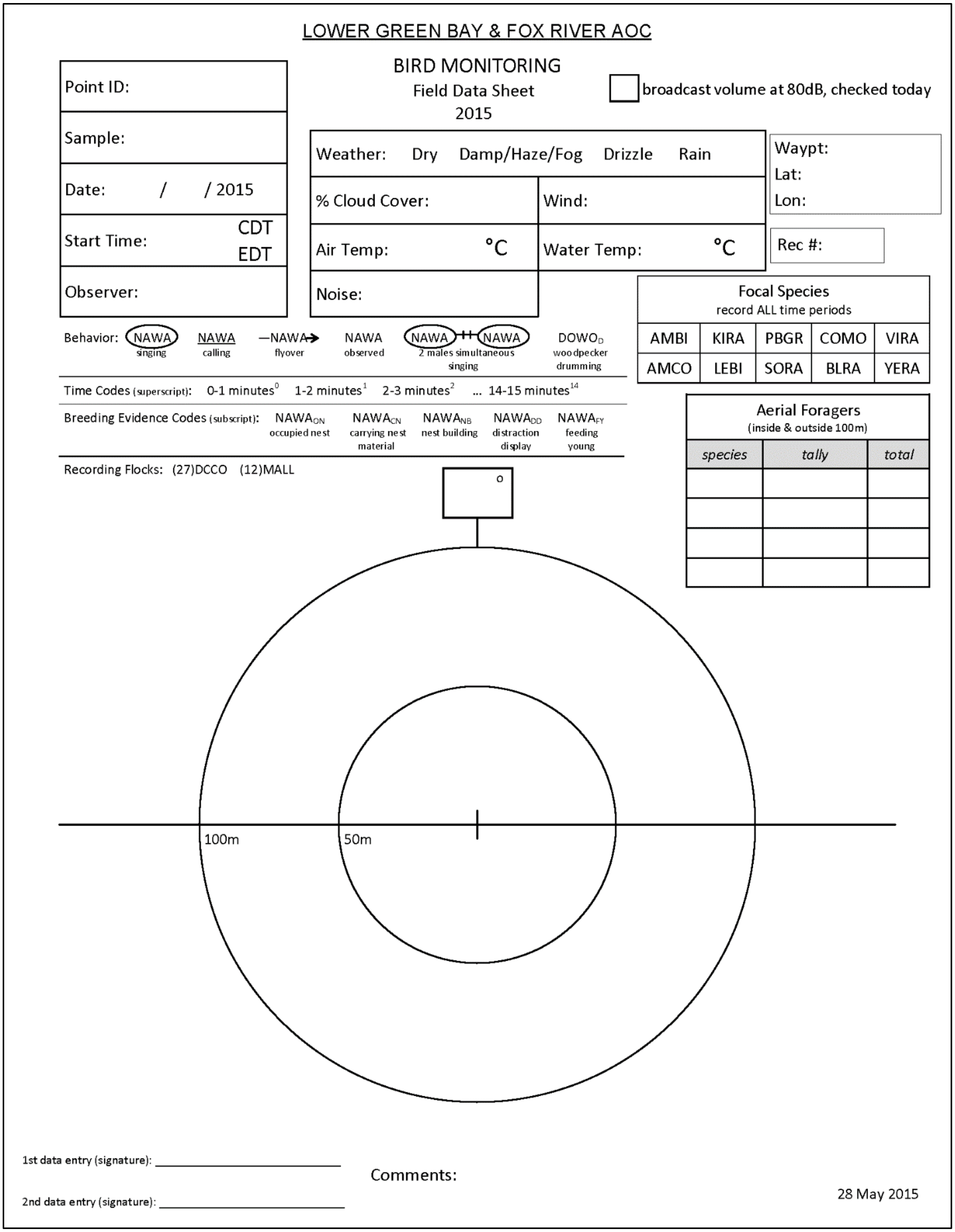
Location	**Latitude (dd.ddddd)**	**Longitude (dd.ddddd)**	**Waypoint #**	**3D (✓)**	**Directions / Notes**
Car Park					
Survey Point					

Record the bearing here: ______

Site Description (dominant plant species, flowers in bloom, etc.)

Other Notes:

Figure 2. Sample Site Description form filled out for each point count location that documents the location's name and geospatial coordinates, safe parking locations, dominant plants, compass bearing (used for repeatability of anuran and wetland bird surveys), and any other important notes.



LOWER GREEN BAY & FOX RIVER AOC

BIRD MONITORING
Field Data Sheet
2015

☐ broadcast volume at 80dB, checked today

Point ID:

Sample:

Date: / / 2015

Start Time: CDT EDT

Observer:

Weather: Dry Damp/Haze/Fog Drizzle Rain

% Cloud Cover:

Wind:

Air Temp: °C

Water Temp: °C

Noise:

Waypt:
Lat:
Lon:

Rec #:

Behavior: NAWA singing, NAWA calling, —NAWA→ flyover, NAWA observed, NAWA ⊣⊢ NAWA 2 males simultaneous singing, DOWO$_D$ woodpecker drumming

Time Codes (superscript): 0-1 minutes^0 1-2 minutes^1 2-3 minutes^2 … 14-15 minutes^{14}

Breeding Evidence Codes (subscript): NAWA$_{ON}$ occupied nest NAWA$_{CN}$ carrying nest material NAWA$_{NB}$ nest building NAWA$_{DD}$ distraction display NAWA$_{FY}$ feeding young

Recording Flocks: (27)DCCO (12)MALL

Focal Species
record ALL time periods

AMBI	KIRA	PBGR	COMO	VIRA
AMCO	LEBI	SORA	BLRA	YERA

Aerial Foragers
(inside & outside 100m)

species	*tally*	*total*

1st data entry (signature): ____________________

2nd data entry (signature): ____________________

Comments:

28 May 2015

Figure 3. Sample wetland bird point count data sheet modified from the Great Lakes Coastal Wetland Monitoring Program bird data form (Great Lakes Coastal Wetlands Consortium 2014, p. 136, Uzarski et al. 2017) that was used for summer 2015 field surveys.

Appendix 1.2: Surveys in Non-Open Wetland Habitats (2015)

Field Work

We also identified an information gap on using standardized methods to survey birds in a variety of non-open wetland habitats in the LGB&FR AOC, particularly along the Fox River and west shore, in habitats including forested wetlands, upland forests, isolated forests in suburban areas, early successional forests, old fields, restore oak savanna, shrub-dominated habitats, and riparian habitats. Thus, Erin Giese and a student assistant, Stephanie Beilke, scouted and identified 23 locations (Figure 1, Appendix 1.2) within the LGB&FR AOC that trained UW-Green Bay students surveyed for birds in the summer of 2015. Once a point count location was established, Giese and Beilke filled out a Site Description form (one per location), which documents the location's name and geospatial coordinates, safe parking areas, dominant plants, property information, and any other helpful notes (Figure 2, Appendix 1.1).

Birds were sampled following the methods outlined in Knutson et al. (2008), a widely accepted, western Great Lakes region-wide protocol. Trained observers conduct a 10-minute, unlimited-distance point count by recording all birds seen or heard regardless of how far away an individual was calling from the observer. All species, number of individuals, and the minute and distance an individual was first detected were recorded on the point count form (Figure 2, Appendix 1.2). Each point count location was visited one time in late June or early July 2015. Surveys were conducted during relatively good weather conditions with minimal wind and precipitation. Basic weather information (cloud cover, wind, and air temperature), start time, and geospatial coordinates of point count locations were collected at each survey.

Six UW-Green Bay students (advanced undergraduates or graduates) were trained on how to conduct wetland bird surveys on 23 and 26 March 2015 and also met individually with Giese to further discuss these non-open wetland surveys. For safety purposes, surveys were conducted by a team of two students, in which one student conducted the survey itself and the other student collected the basic weather information, helped with navigation, and collected geospatial coordinates of the point count locations. Students who conducted the bird surveys passed the required, rigorous wetland bird certification test, as is done for the CWMP (see QAPP section "Personnel, Special Training Requirements, or Certifications"), and have been doing bird surveys for many years across many different habitat types in the Great Lakes region using protocols similar to Knutson et al.'s (2008).

Data Entry

After the field season, two UW-Green Bay students double entered bird data into a MS Excel spreadsheet created by Giese that employed data validation techniques to minimize data entry error; the two entries were subsequently compared to produce a final, high quality data set (see "Data Management" for more details on data entry). Accompanying metadata were later added.

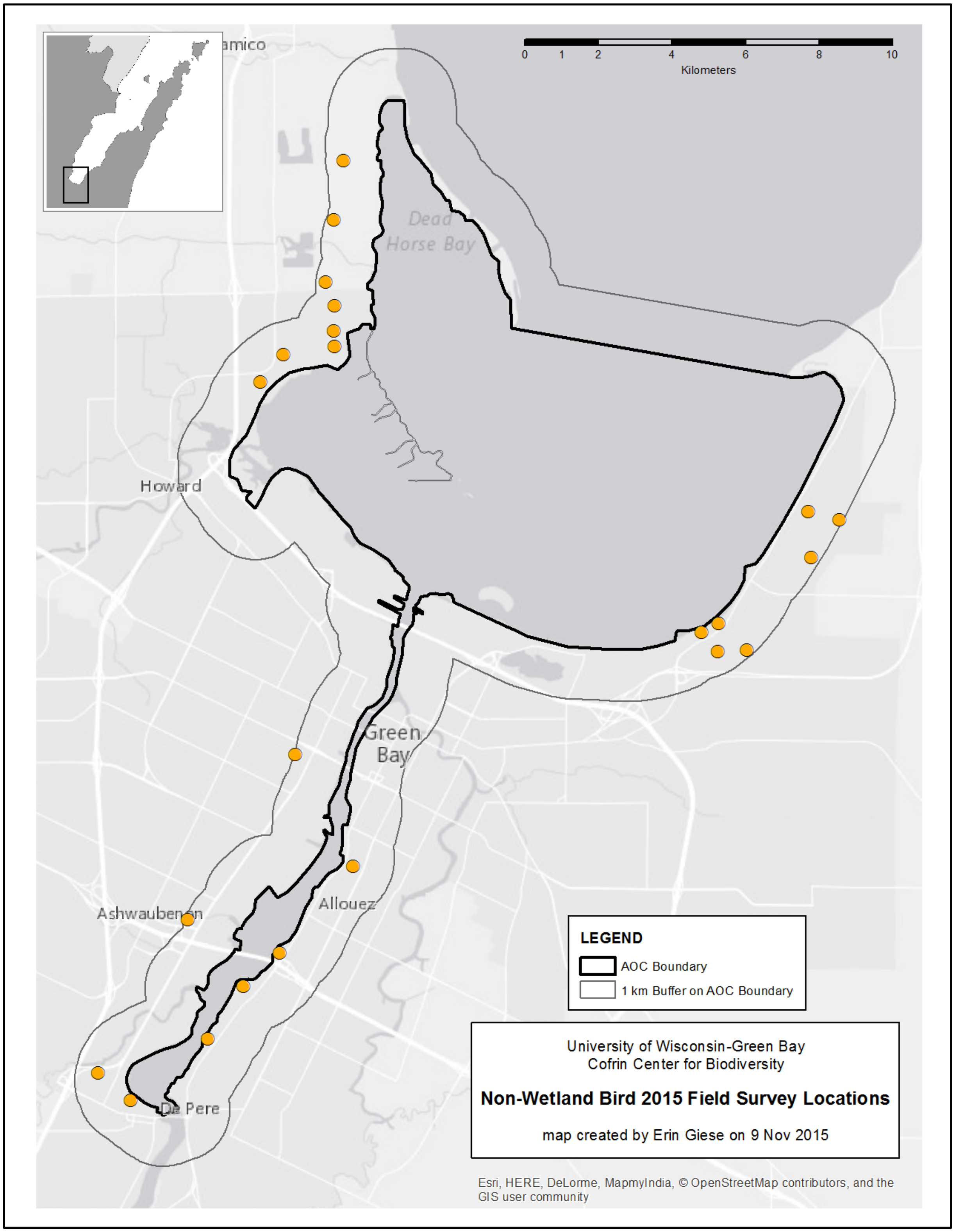
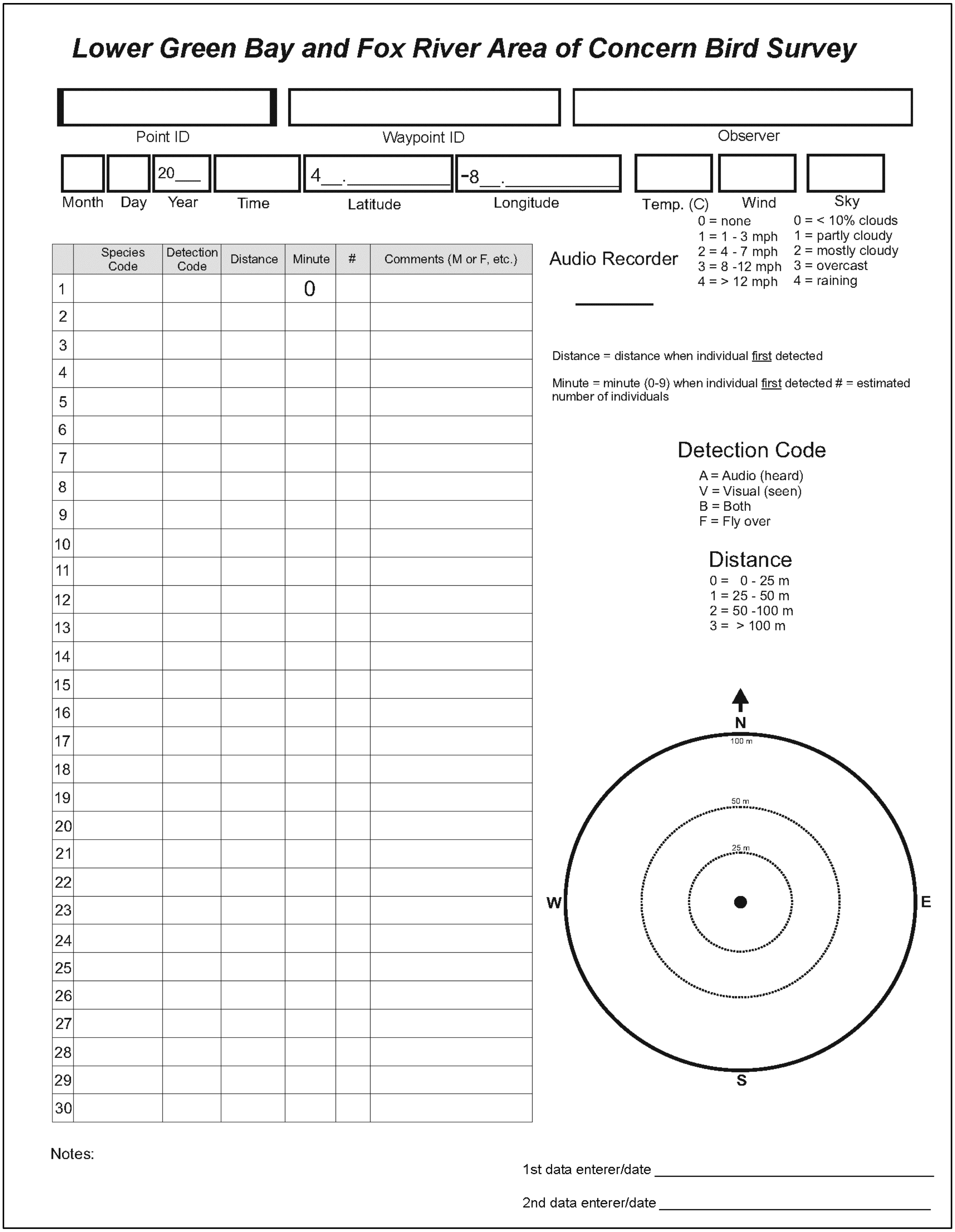


Figure 1. Point count locations (n = 23) positioned in a variety of habitats (e.g., forested wetlands, old fields, upland forest, isolated forests in suburban areas) that were surveyed for birds in the summer of 2015. They are located within 1 km of shoreline at Lake Michigan/Green Bay high water level of 177.2 m AMSL in the Lower Green Bay and Fox River Area of Concern in Wisconsin. Basemap sources: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community. Map created in ArcGIS 10.3.1 (Environmental Systems Research Institute 2015).



Lower Green Bay and Fox River Area of Concern Bird Survey

Point ID ______ Waypoint ID ______ Observer ______

Month ______ Day ______ Year 20___ Time ______ Latitude 4__.________ Longitude -8__.________ Temp. (C) ______ Wind ______ Sky ______

Wind
0 = none
1 = 1 - 3 mph
2 = 4 - 7 mph
3 = 8 -12 mph
4 = > 12 mph

Sky
0 = < 10% clouds
1 = partly cloudy
2 = mostly cloudy
3 = overcast
4 = raining

	Species Code	Detection Code	Distance	Minute	#	Comments (M or F, etc.)
1				0		
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						

Audio Recorder ______

Distance = distance when individual <u>first</u> detected

Minute = minute (0-9) when individual <u>first</u> detected # = estimated number of individuals

Detection Code

A = Audio (heard)
V = Visual (seen)
B = Both
F = Fly over

Distance

0 = 0 - 25 m
1 = 25 - 50 m
2 = 50 -100 m
3 = > 100 m

Notes:

1st data enterer/date ______________________

2nd data enterer/date ______________________

Figure 2. Sample bird point count data sheet used for the summer 2015 bird surveys (in non-open wetland habitats) that was modified from bird data forms used at the University of Wisconsin-Green Bay's Cofrin Center for Biodiversity and that is based on the Knutson et al. (2008) protocol.

Appendix 1.3: Surveys of Migratory Waterfowl (2016-2017)

These surveys were funded under a different GLRI grant than the rest of this report

Purpose

Migratory waterfowl comprise one of the most historically, culturally, and economically important elements of the Green Bay ecosystem. Yet, no long-term systematic or standardized monitoring has taken place in the LGB&FR AOC, though some attempts have been made to study waterfowl usage in lower Green Bay (e.g., UW-Green Bay master's thesis by Vicky Harris, 1998). Unfortunately, most standardized waterfowl surveys are conducted from airplanes with bird biologists counting birds from the air. Airplane surveys can be expensive and logistically difficult to coordinate.

Therefore, we developed and implemented a systematic, repeatable method for surveying migratory waterfowl in the LGB&FR AOC from permanent ground survey points. Specific objectives for this aspect of the project are as follows:

1. Identify and map locations where waterfowl stage within the LGB&FR AOC during fall 2016, winter 2016-17, and spring 2017 migratory periods.
2. Describe waterfowl species composition and estimate seasonal numbers of individuals in the LGB&FR AOC.
3. Describe how waterfowl distributions change throughout each migratory period and across seasons.
4. Compare data collected at ground survey points with aerial sampling and describe how these field methodologies differ.

Ground-based Waterfowl Surveys

With the assistance of Howe, Wolf, and Giese, Waterfowl Expert, Tom Prestby, established eight permanent, land-based sampling points within the LGB&FR AOC based on their local expert knowledge on where waterfowl are known to stage and where there are easily accessible locations (Figure 1, Appendix 1.3):

- Three points on the west shore of the bay of Green Bay;
- Three points on the east shore of the bay of Green Bay;
- One point at the mouth of the Fox River; and
- One point at the De Pere Dam by Voyageur Park.

They also established two reference locations (Sensiba State Wildlife Area; Bay Shore County Park) in order to compare waterfowl usage in the LGB&FR AOC (Figure 1, Appendix 1.3). Prestby scouted and refined these 10 locations and filled out a Site Description form (one per location), which documents the location's name and geospatial coordinates, safe parking areas, property information, and any other helpful notes (Figure 2, Appendix 1.3).

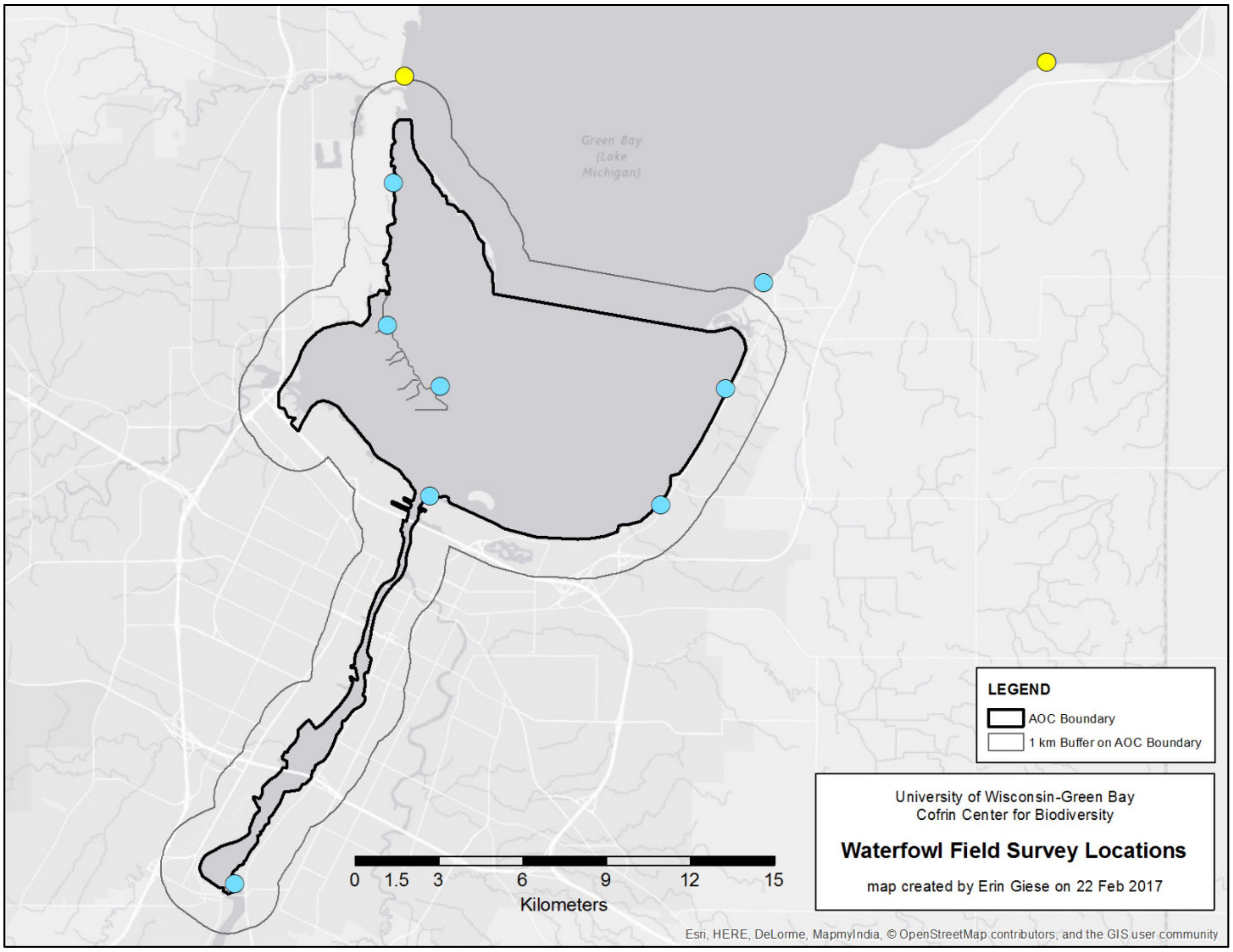
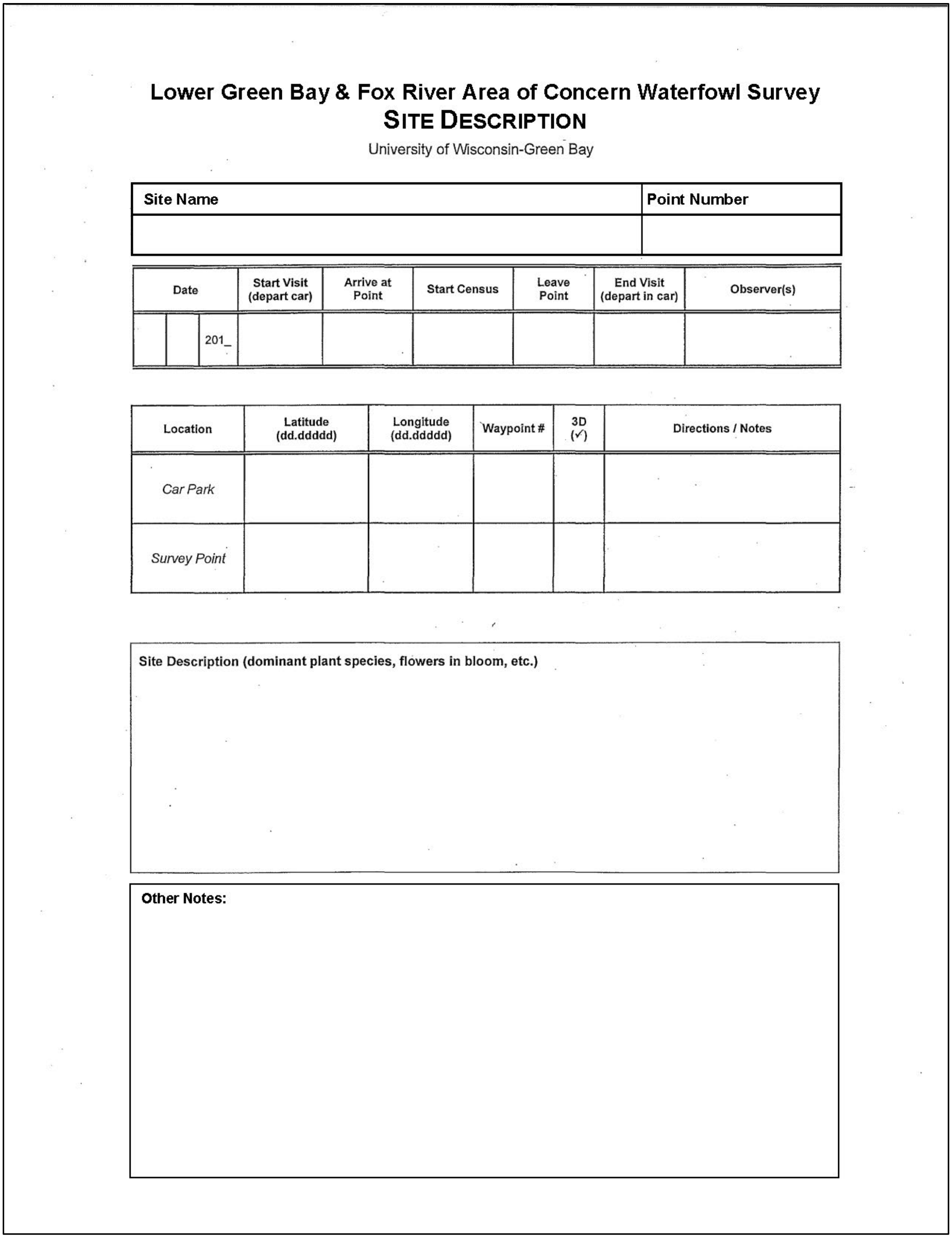


Figure 1. Point count locations (n = 10) that were surveyed for waterfowl in fall 2016, winter 2016-17, and spring 2017 in the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC). Eight points (blue circles) were established to document waterfowl usage within the LGB&FR AOC: three points along the west shore, two points on the Fox River, and three points on the east shore. Two reference points (yellow circles) were established in order to make comparisons with the LGB&FR AOC. Note that although the northernmost point along the east shore next to Point au Sable (not the reference point) is technically outside the project study area (1 km buffer from LGB&FR AOC boundary), waterfowl rafts were documented both inside and outside the project study area. Basemap sources: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community. Map created in ArcGIS 10.3.1 (Environmental Systems Research Institute 2015).



Lower Green Bay & Fox River Area of Concern Waterfowl Survey
SITE DESCRIPTION
University of Wisconsin-Green Bay

Site Name	Point Number

Date			Start Visit (depart car)	Arrive at Point	Start Census	Leave Point	End Visit (depart in car)	Observer(s)
		201_						

Location	Latitude (dd.ddddd)	Longitude (dd.ddddd)	Waypoint #	3D (✓)	Directions / Notes
Car Park					
Survey Point					

Site Description (dominant plant species, flowers in bloom, etc.)

Other Notes:

Figure 2. Sample Site Description form filled out for each waterfowl point count location that documents the location's name and geospatial coordinates, safe parking locations, description of the overall view of the bay of Green Bay, and any other important notes.

Howe, Wolf, Prestby, and Giese developed the following systematic, repeatable field protocol for surveying migratory waterfowl from land in the LGB&FR AOC during the fall, winter, or spring (sample data form in Figures 3a,b, Appendix 1.3):

1. Sample each of the 10 permanent, ground-based sampling locations approximately twice a week throughout each season, so long as there is open water.
    a. Do not survey when visible area of water from survey location is >90% ice-covered.
    b. Check ice coverage at all points, especially in beginning and end of winter, because ice shifts unpredictably.
    c. Randomize order of surveys to eliminate biases due to time of day.
        i. West shore and east shore points can be surveyed together for logistical reasons but randomize order of points therein. Avoid conditions likely to decrease detectability associated with time of day, especially surveying toward a low sun angle in clear or partly cloudy conditions.

2. Surveys may be conducted during the following dates by season:
    a. Fall: August 15 - November 30
    b. Winter: December 1 - February 28
    c. Spring: March 1 - May 31

    Seasonal dates are defined by the Wisconsin Society for Ornithology (https://wsobirds.org/report-sightings). Surveys began on 12 October 2016 immediately after funding was obtained and ended in May 2017 when migratory waterfowl concentrations had ceased.

3. Surveys should be conducted during relatively good weather conditions with good visibility (not during thick fog or if waves affect line of sight), but not during heavy rain or very high wind.

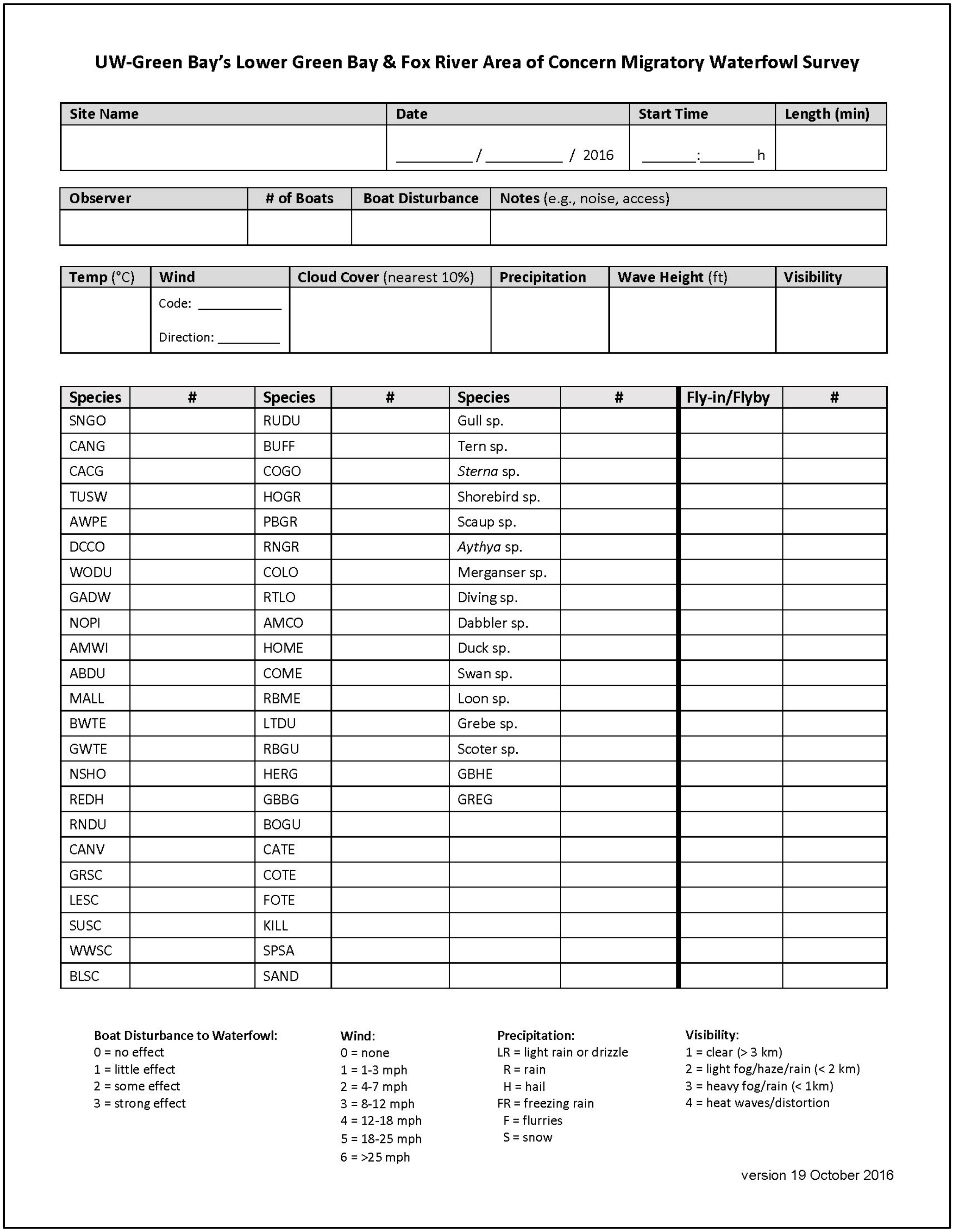
4. Surveys may be conducted at any time during daylight hours.

5. Record the following basic information about the count:
    a. Site name
    b. Date
    c. Start time (using the 24-hr clock; 13:00 h = 1:00 pm)
    d. Length of survey (in minutes)
    e. Observer
    f. # of boats
    g. Boat disturbance: use one of the following codes:
        i. 0 = no effect
        ii. 1 = little effect
        iii. 2 = some effect
        iv. 3 = strong effect
    h. Notes (e.g., noise, access)
    i. Temperature (in °C)
    j. Wind: record wind direction (e.g., NW) and one of the following wind speed codes:
        i. 0 = none
        ii. 1 = 1-3 mph (1.6-4.8 kph)
        iii. 2 = 4-7 mph (6.4-11.3 kph)
        iv. 3 = 8-12 mph (12.9-19.3 kph)
        v. 4 = 12-18 mph (19.3-29.0 kph)

        - vi. 5 = 18-25 mph (29.0-40.2 kph)
        - vii. 6 = >25 mph (>40.2 kph)
        - viii. Note that wind speed was not collected with an instrument but rather estimated by observer.
    - k. Cloud cover (estimate to the nearest 10%)
    - l. Precipitation: use one of the following codes:
        - i. LR = light rain or drizzle
        - ii. R = rain
        - iii. H = hail
        - iv. FR = freezing rain
        - v. F = flurries
        - vi. S = snow
    - m. Wave height (estimate in feet)
    - n. Visibility
        - i. 1 = clear (>3 km)
        - ii. 2 = light fog/haze/rain (<2 km)
        - iii. 3 = heavy fog/rain (<1 km)
        - iv. 4 = heat waves/distortion

6. Conducting the survey:
    - a. Conduct an unlimited-distance point count by counting the number of individuals of each waterfowl (e.g., ducks, geese, mergansers) and waterbird species (e.g., gulls, terns, shorebirds, etc.) that are actively using open water and shoreline, regardless of how far away an individual is. Or, estimate to nearest 100, 1,000, 5,000, or 10,000. Record these counts or estimates in the six columns left of the solid black vertical line on the data form (Figure 3a, Appendix 1.3) next to the appropriate species or species group (e.g., grebe sp.).
    - b. When an individual or group of waterfowl cannot be identified, which is common due to distance, lighting, or waves, record as the species or family group that the individual or group can most safely be identified to. Options range from “scaup sp.” to “waterfowl sp.”
    - c. Draw waterfowl rafts on the back of the data form for the appropriate point count location (e.g., Figure 3b, Appendix 1.3) by drawing a polygon shape that represents the raft and recording the species and estimated number of individuals.
        - i. Also draw ice coverage on map and other notable occurrences affecting waterfowl identification or congregation including severe glare or hunters.
    - d. Record the species (or species group) and count the number of individuals of waterfowl that fly by the area being surveyed but that do not stay and actively use the water. These observations are called “Fly-ins” or “Fly-bys” and are recorded in the two columns to the right of the solid black vertical line on the data form (Figure 3a, Appendix 1.3).
        - i. “Fly-ins/Flybys” are generally not recorded on the map on the back of the data form. However, notable groups can be recorded with an arrow starting on one side of the bird code label and ending on the other, indicating the direction of flight.
    - e. Each point count is 15 minutes in length at a minimum. If all waterfowl can be accurately recorded and counted in 15 minutes, then the count ends at 15 minutes. If there is a large number of waterfowl to record and the observer needs more than 15 minutes, then the observer stays to accurately count all waterfowl for however long it takes to count them.

f. An observer should use a handheld tally counter (e.g., Sparco Hand Tally Counter) to quickly count or estimate large waterfowl rafts.
g. High-quality optics are required for these unlimited-distance point counts. In 2017, Prestby used a Swarovski 80 HD spotting scope and Swarovski 8 x 42 EL binoculars. A rangefinder is recommended for estimating distances.



UW-Green Bay's Lower Green Bay & Fox River Area of Concern Migratory Waterfowl Survey

Site Name	**Date**	**Start Time**	**Length (min)**
	_________ / _________ / 2016	______:______ h	

Observer	**# of Boats**	**Boat Disturbance**	**Notes** (e.g., noise, access)

Temp (°C)	**Wind**	**Cloud Cover** (nearest 10%)	**Precipitation**	**Wave Height** (ft)	**Visibility**
	Code: ___________ Direction: _________				

Species	**#**	**Species**	**#**	**Species**	**#**	**Fly-in/Flyby**	**#**
SNGO		RUDU		Gull sp.			
CANG		BUFF		Tern sp.			
CACG		COGO		*Sterna* sp.			
TUSW		HOGR		Shorebird sp.			
AWPE		PBGR		Scaup sp.			
DCCO		RNGR		*Aythya* sp.			
WODU		COLO		Merganser sp.			
GADW		RTLO		Diving sp.			
NOPI		AMCO		Dabbler sp.			
AMWI		HOME		Duck sp.			
ABDU		COME		Swan sp.			
MALL		RBME		Loon sp.			
BWTE		LTDU		Grebe sp.			
GWTE		RBGU		Scoter sp.			
NSHO		HERG		GBHE			
REDH		GBBG		GREG			
RNDU		BOGU					
CANV		CATE					
GRSC		COTE					
LESC		FOTE					
SUSC		KILL					
WWSC		SPSA					
BLSC		SAND					

Boat Disturbance to Waterfowl:
0 = no effect
1 = little effect
2 = some effect
3 = strong effect

Wind:
0 = none
1 = 1-3 mph
2 = 4-7 mph
3 = 8-12 mph
4 = 12-18 mph
5 = 18-25 mph
6 = >25 mph

Precipitation:
LR = light rain or drizzle
R = rain
H = hail
FR = freezing rain
F = flurries
S = snow

Visibility:
1 = clear (> 3 km)
2 = light fog/haze/rain (< 2 km)
3 = heavy fog/rain (< 1km)
4 = heat waves/distortion

version 19 October 2016

Figure 3a. Sample waterfowl point count data sheet used during fall 2016, winter 2016-17, and spring 2017 surveys. Waterfowl rafts were mapped on paper maps (Figure 3b, Appendix 1.3) on the back of this data form.

Figure 3b. Sample map for waterfowl point count location, Long Tail01, where waterfowl rafts are drawn and recorded. Bird species and total number of individuals were recorded in a table on the front side of this data form (Figure 3a, Appendix 1.3). Map created by UW-Green Bay undergraduate student Cody Becker using ArcGIS 10.5 (Environmental Systems Research Institute 2016).

Aerial Waterfowl Surveys

In order to compare ground-based waterfowl surveys with aerial sampling (the project's fourth objective), Prestby and Giese explored waterfowl documentation from a small Cessna 172 airplane on 2 December 2016 (Figure 4, Appendix 1.3). They hired a pilot from the Green Bay CAVU Flight Academy to fly them over the LGB&FR AOC near the ten waterfowl point count locations and practice documenting waterfowl. They flew out of the Austin Straubel International Airport in Green Bay, Wisconsin.

Figure 4. Out of the Austin Straubel International Airport in Green Bay, Wisconsin, waterfowl expert, Tom Prestby (pictured above), and Erin Giese flew with a CAVU Flight Academy pilot in a Cessna 172 airplane over the Lower Green Bay and Fox River Area of Concern on 2 December 2016. In flight, Prestby tried counting and documenting waterfowl usage while Giese took photographs of waterfowl and waterbirds. Photograph taken by Giese.

Counting Waterfowl

Throughout the duration of the flight, the pilot flew at an altitude of around 1,000 ft (300 m), which is two to three times as high as other local aerial waterfowl sampling (H. J. "Bud" Harris, *pers. comm.*, from surveys in the 1990s). Flying at such a high altitude made it difficult for Prestby to estimate numbers of waterfowl and for Giese to take photographs of the waterfowl. It was also dark and overcast during the flight, which created low light conditions and limited visibility.

Without using binoculars, Prestby simultaneously described the waterfowl he saw (recording species and estimated numbers of individuals) by speaking into an audio recorder (Sony PCM-D50) and marked waypoints using a GPS unit to geospatially record their locations in the air (Figures 5 and 6, Appendix 1.3). Because they were flying at such a high altitude and it was a dark, overcast day, Prestby was only able to identify waterfowl using the following species groups (not individual species): gulls, mergansers, scaup, goldeneye, and cormorants. In other cases, he could only record waterfowl rafts as unidentified ducks. Prestby later transcribed the waterfowl data from the audio recorder and GPS unit into a MS Excel table. Taking photographs of waterfowl groups also proved to be very difficult because of the altitude and poor weather conditions (Figure 7a,b, Appendix 1.3). Instead, Giese took many aerial photographs of the

LGB&FR AOC landscape and "priority areas" (e.g., Point au Sable, Peters Marsh, Cat Island Chain Restoration Site), which are included in this report (Appendix 10).

Figure 5. Tom Prestby documenting waterfowl species by speaking into an audio recorder (Sony PCM-D50) and marking geospatial locations with a GPS unit in a Cessna 172 airplane on 2 December 2016. Photograph taken by Erin Giese.

On the afternoon of December 2, 2016, only 2-3 hours after aerial surveys, Prestby conducted point counts at some of the established survey locations (Bay Shore County Park, Point au Sable, Communiversity Park) to compare on-the-ground survey results directly to aerial survey results.

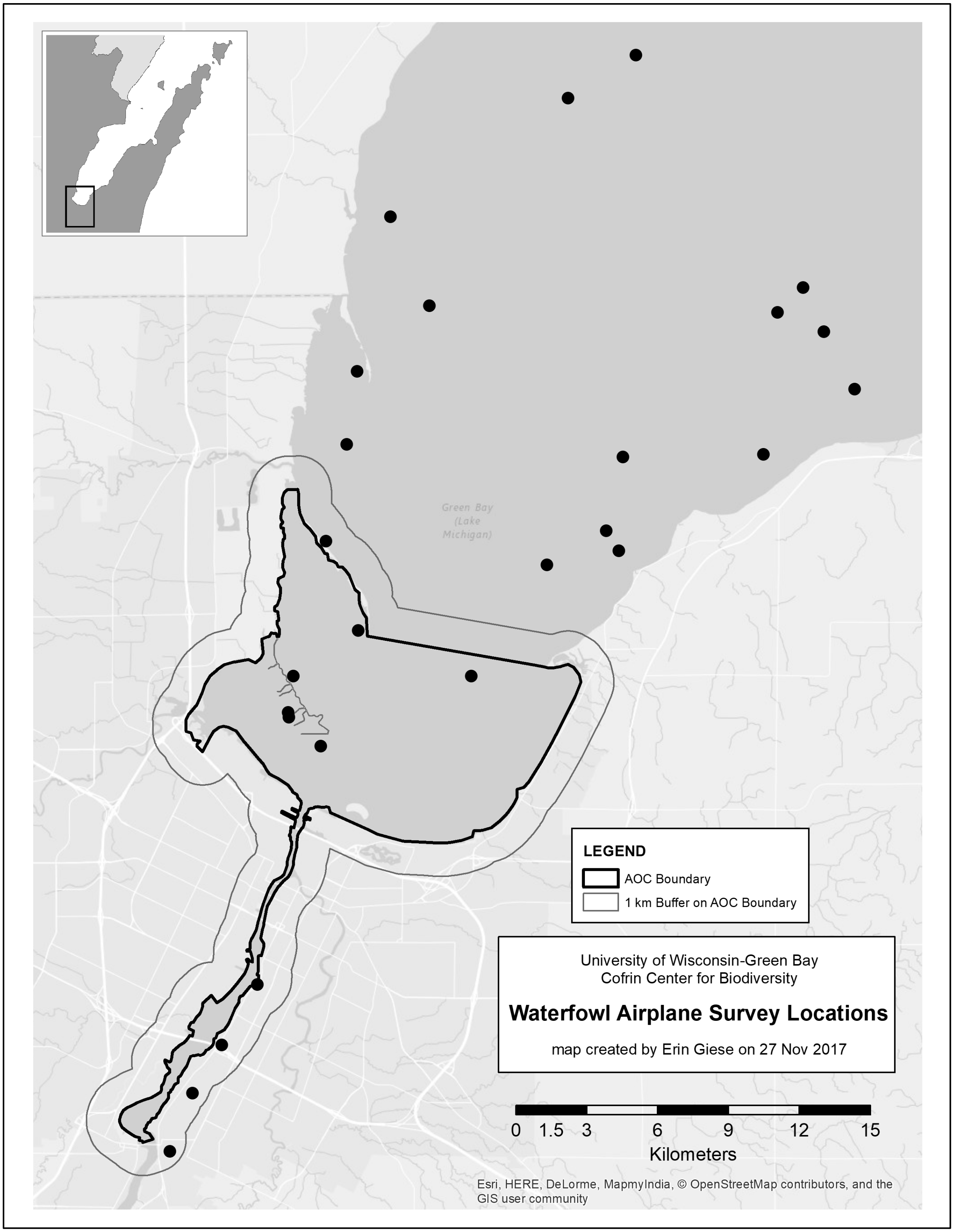


Figure 6. Locations (n = 26) of general areas that contained waterfowl that Tom Prestby noted while being flown in a Cessna 172 airplane on 6 December 2016. Basemap sources: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community. Map created by Erin Giese in ArcGIS 10.5 (Environmental Systems Research Institute 2016).

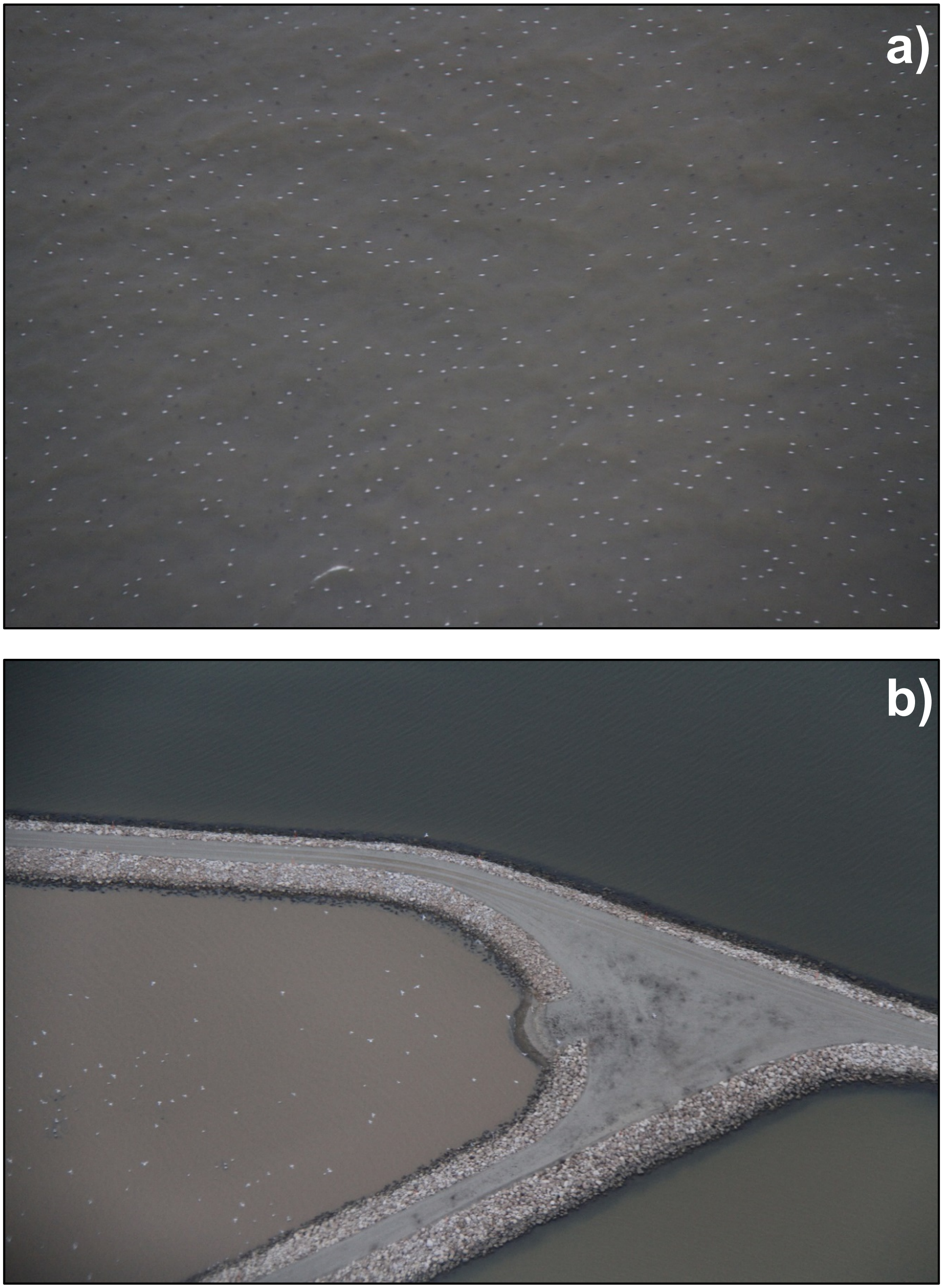


Figure 7. Sample waterfowl photographs of waterfowl (e.g., ducks, gulls) taken by Erin Giese while flying in a Cessna 172 on 2 December 2016. The top photograph (a) was taken over open water in the LGB&FR AOC. The bottom photograph (b) was taken above the Cat Island Chain Restoration Site. Because the airplane maintained an altitude of around 300 m (1,000 ft) and the weather was overcast, it was extremely difficult to take photographs of waterfowl and to identify them. The small white and black dots are gulls and other waterfowl.

Photo Documentation and Processing

Erin Giese took seven videos and 208 photographs, primarily documenting LGB&FR AOC “priority areas” since the airplane was too high to take photographs of waterfowl, though she also took a few photographs of groups of waterfowl. They were digitally organized into folders based on the site or general area they were taken at.

Data Management and Archiving

Giese designed a data management system for organizing and backing up incoming field data. Within a few days of conducting a waterfowl survey, Prestby would provide Giese with his completed data forms. Giese audited each data form and then scanned and organized the forms digitally. Implementing these strict data back-up procedures ensured no data were lost.

Data Entry

After the field season, Prestby carefully entered the raw tabular waterfowl data from his ground-based surveys into a MS Excel spreadsheet created by Giese that employed data validation techniques to minimize data entry error. Prestby and Giese wrote accompanying metadata and produced a final, high quality data set. UW-Green Bay undergraduate student, Cody Becker, used ArcGIS 10.5 (Environmental Systems Research Institute 2016) to digitize every waterfowl raft for each point count conducted (see section GIS Digitizing of Waterfowl Rafts). Prestby proofed all data entry by comparing the data forms to the MS Excel data entry document.

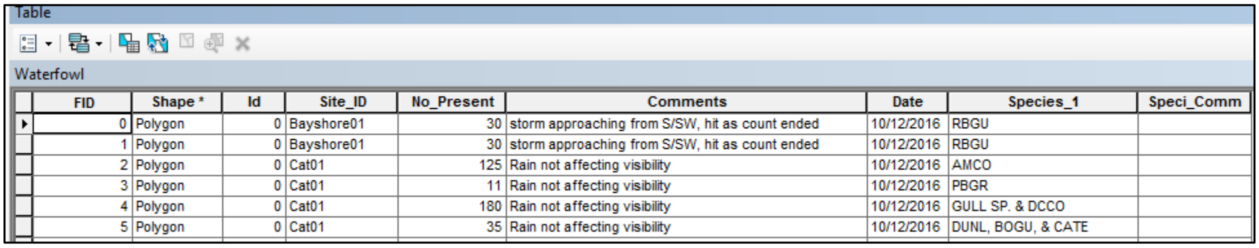
Prestby also transcribed the waterfowl observations he collected during the 2 December 2016 flight using an audio recorder and GPS unit into a MS Excel table.

Workflow Summary of Digitizing of Waterfowl Rafts in GIS (written by Cody Becker)

Overview

Prestby’s field data were collected on double-sided paper forms. One side of the form has a map with hand drawn polygons of waterfowl rafts. Each polygon had a 4-8 digit species code assigned to them. On the other side, there was a table with species codes and the number of each species present, date, time, weather conditions, and comments. The polygons were digitized in ArcMap and the attribute table was generated using the date, site ID, comments, and species present found on the front page.

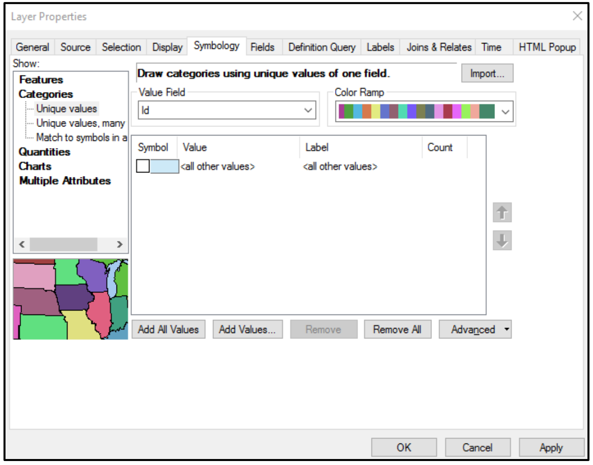
Each polygon is represented as a record in the attribute table (see below). The added fields include *No_Present* (number of species present), *Comments*, *Date* (mm/dd/yyyy), *Species_1* (Species ID), and *Speci_Comm* (Species common name). The data for each field can be found on the front page of the field data forms.



FID	Shape *	Id	Site_ID	No_Present	Comments	Date	Species_1	Speci_Comm
0	Polygon	0	Bayshore01	30	storm approaching from S/SW, hit as count ended	10/12/2016	RBGU	
1	Polygon	0	Bayshore01	30	storm approaching from S/SW, hit as count ended	10/12/2016	RBGU	
2	Polygon	0	Cat01	125	Rain not affecting visibility	10/12/2016	AMCO	
3	Polygon	0	Cat01	11	Rain not affecting visibility	10/12/2016	PBGR	
4	Polygon	0	Cat01	180	Rain not affecting visibility	10/12/2016	GULL SP. & DCCO	
5	Polygon	0	Cat01	35	Rain not affecting visibility	10/12/2016	DUNL, BOGU, & CATE	

Initial Preparation

- Open existing “WaterfowlRaft_10.4.mxd” or create a new .mxd in ArcMap
  - For new .mxd, add “Waterfowl” and “WaterfowlSurveyPts” shapefiles
  - Add a basemap or satellite photos of Brown County
    - In the original basemap, Becker downloaded photos from the National Map Viewer (https://viewer.nationalmap.gov/basic/?howTo=true) and used the “Mosaic to New Raster” tool in ArcToolbox merge all photos together
- Change the symbology of the Waterfowl layer (see reference photo below)
  - Right click on the Waterfowl layer in the Table of Contents Pane
  - Select “Properties”
  - Navigate to the “Symbology” tab and select “Categories” from the list
  - Change the “Value Field” to the “Date” attribute using the dropdown list

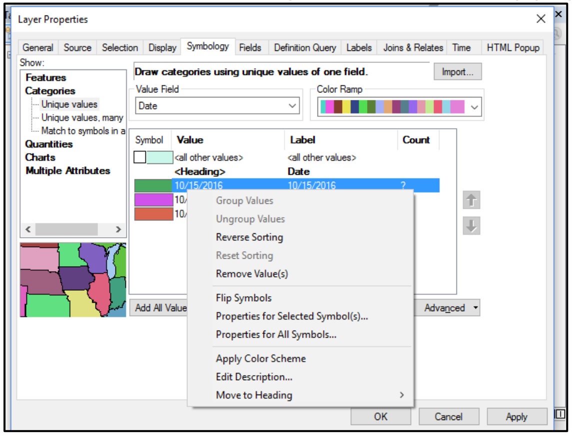


Draw categories using unique values of one field.

Value Field: Id

Symbol	Value	Label	Count
☐	<all other values>	<all other values>	

  - Uncheck the “<all other values>” box and select “Add Values” from the bottom toolset
    - Choose the dates you wish to view from the box using the CTRL+Click method, if not, all dates show up select the “Complete List” button
      - **NOTE:** This will add the dates from the attribute table, but **WILL NOT** add new dates, see below for more information
    - Unwanted values can be removed (see below) by right clicking the unwanted date and selecting “Remove Value(s)” (see below)



Draw categories using unique values of one field.

Value Field: Date

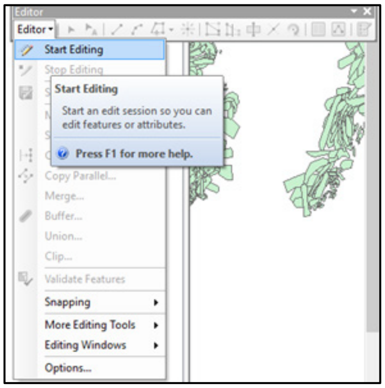
Symbol	Value	Label	Count
☐	<all other values>	<all other values>	
	<Heading>	Date	
	10/15/2016	10/15/2016	?
	10/		
	10/		

  - Click “Apply” and “OK” to apply settings

    - Repeat the above steps to customize what is visible on the map by using the “Add Values” button

Adding New Polygons and New Dates

- To add new polygons, select “Start Editing” from the Editor Toolbar (see below) and edit the “Waterfowl” shapefile
    - Demo polygons need to be added for new dates to be included in attribute table and to show up on the Create Feature Pane



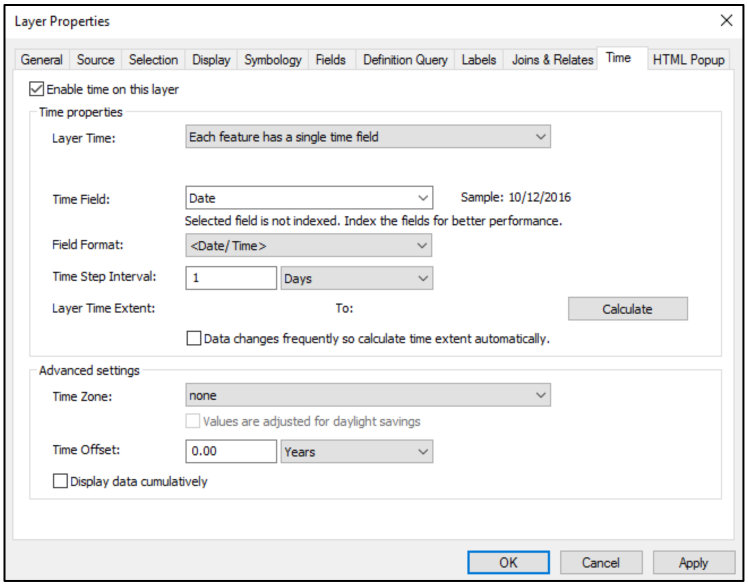
Start an edit session so you can edit features or attributes.

- Create a new polygon using the Create Feature Pane
    - Select the date you wish to draw from the Create Feature Pane to create a polygon from an existing date
    - To create a new date, you must select a date from the Create Feature Pane and draw a DEMO polygon somewhere outside of the survey areas
        - Once the polygon is drawn, enter new date in attribute table and out “DEMO” in the comments section
        - Once all data has been entered, delete the “DEMO” polygons. The DEMO polygons act as placeholders for the editing process
            - **NOTE:** Adding polygons with new dates does not show up in the Create Feature Pane, so the “Waterfowl” shapefile edits must be saved, removed from the .mxd, and re-added before the changes are visible (possible ArcMap bug)
    - Periodically save edits using the Editor toolbar by selecting the “Save Edits” button from the dropdown list
- Once all data are entered, backup the “Waterfowl” and “WaterfowlSurveyPts” shapefile

Enabling Time on a Layer

Time-lapse animations can be generated in ArcMap by using the time features built into each layer. So far, Becker has had mixed results with the time-lapse features due to potential bugs within ArcMap. There is a link to the official Esri documentation here: http://desktop.arcgis. com/en/arcmap/10.3/map/time/enabling-time-on-your-data.htm.

- Open the shapefile containing a basemap or orthoimagery, the “Waterfowl” shapefile, and the “WaterfowlSurveyPts” shapefile
- Right click on the Waterfowl layer and select “Properties” from the dropdown menu
- Navigate to the “Time” tab (see below)



☑ Enable time on this layer

Time properties

Layer Time: Each feature has a single time field

Time Field: Date

Sample: 10/12/2016

Selected field is not indexed. Index the fields for better performance.

Field Format: <Date/ Time>

Time Step Interval: 1 Days

Layer Time Extent: To:

☐ Data changes frequently so calculate time extent automatically.

Advanced settings

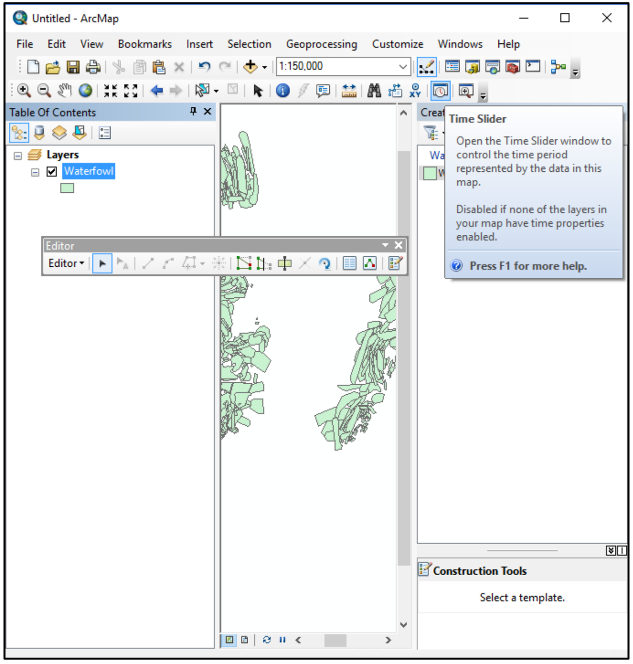
Time Zone: none

☐ Values are adjusted for daylight savings

Time Offset: 0.00 Years

☐ Display data cumulatively

- Check the “Enable Time on this Layer” box
- Make sure the “Time Field” box has “Date” in it
- Change the “Time Step Interval” to 1 Days
- Select “Apply” and “OK” to enable time on the Waterfowl layer
- Navigate to the “Time Slider” button (see image below)
    - **NOTE:** Sometimes the time slider will say “Time is not enabled on this layer” after enabling time. If this is the case, open a new .mxd, add a basemap or orthophotos and the survey points, and go through the enable time process again (possible ArcMap bug)



Open the Time Slider window to control the time period represented by the data in this map.

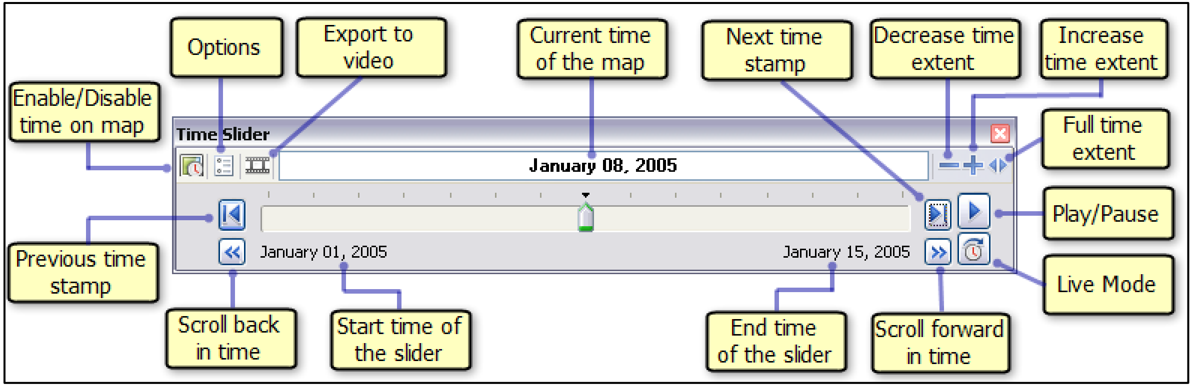
Disabled if none of the layers in your map have time properties enabled.

Press F1 for more help.

Select a template.

Creating and Exporting Animations

- On the Time Slider, there is an option to create and export time animations
- Navigate to the “Options” button (see below)



- Change the Time Step Interval on the “Time Display” tab to 1 day
- Navigate to the “Playback” tab and select the “Play in specified duration (seconds)” button and enter in the length you want the animation to be in seconds
    - This tells ArcMap how long to make your animation, Becker typically uses 4 minutes (240 s), but one will have to experiment to see what works best
- Click the “OK” button to close the Time Slider Options menu
- Click on the “Export to Video” button and navigate to the video save location
    - Give the video a title, and the video will be exported as a .avi file
- Leave all options at their default, click “OK” and let GIS create your animation
    - **NOTE:** Since surveys are not conducted every day within the time period, there will be frames with no visible polygons. It is suggested that one cuts these out using a video editing software such as Windows Movie Maker

Zonal Statistics (Spatial Analyst Toolbox)

- Zonal statistics was used to extract the average depth (from the “**bathygris**” raster) for each waterfowl raft. The data are summarized in the file “**ZonalStatistics_AvgDepthforEachPoly**”
    - **NOTE:** The FID field in “**Waterfowl_NAD_20171009**” = the OID field in “**ZonalStats_20171018.dbf**” and is used to join the two data sets together

Contact Information

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Appendix 2: Anuran Survey Methodology (2015)

Field Work

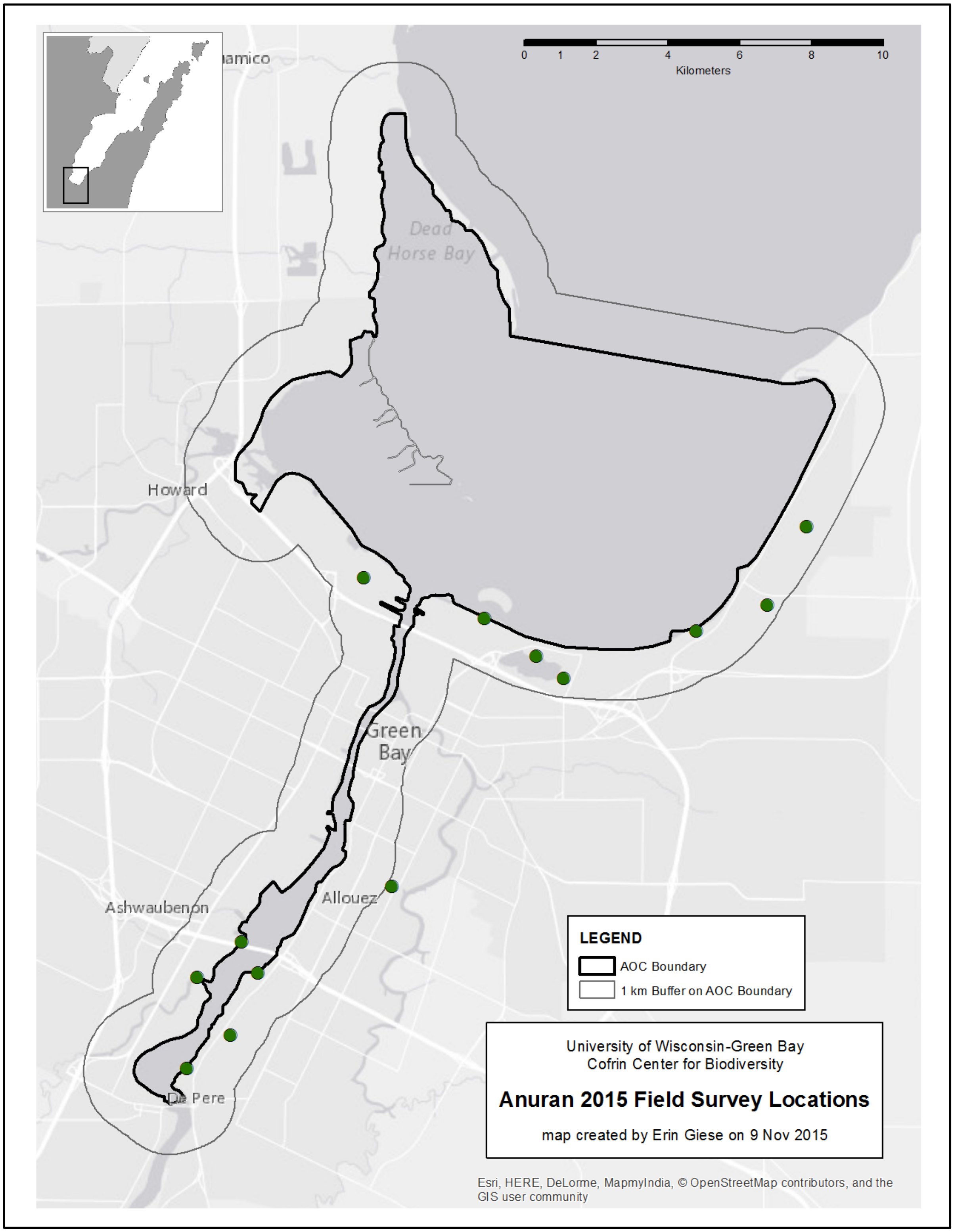
In order to assess the current condition of AOC biota, we started to identify information gaps during Phase I and determined that anurans (frogs/toads only) have only been surveyed in Great Lakes coastal wetlands within the LGB&FR AOC through USEPA-funded projects in which Howe and Giese participate, most recently the Great Lakes Coastal Wetland Monitoring Program (CWMP; 2011-2017; Uzarski et al. 2017; http://www.greatlakes wetlands.org). Small, inland, and fairly open wetlands (primarily dominated by herbaceous plants, such as cattails [*Typha* spp.]) within the LGB&FR AOC (e.g., along the Fox River) have not been recently surveyed for anurans using standardized methods. Under the guidance of Robert Howe and Amy Wolf, Erin Giese and Stephanie Beilke conducted field scouting and identified 13 locations (Figure 1, Appendix 2) within the LGB&FR AOC that trained UW-Green Bay students surveyed for anurans in the spring and summer of 2015. Once a point count location was established, Giese and Beilke filled out a Site Description form (one per location), which documents the location's name and geospatial coordinates, safe parking areas, dominant plants, compass bearing (used for repeatability of anuran and wetland bird surveys), property information, and any other helpful notes (Figure 2, Appendix 1.1).

Anurans were sampled using the same, widely accepted protocol used for the CWMP, namely a 3-minute, unlimited-distance point count, in which trained observers recorded all anurans heard regardless of how far away an individual was calling from the observer (Great Lakes Coastal Wetlands Consortium 2014, pp. 137-141, Uzarski et al. 2017). Numbers of individuals were either counted individually (if calls were not simultaneous), estimated (if some calls were simultaneous), or recorded as a "chorus" (when individuals could not be reliably estimated) on the point count form (Figure 2, Appendix 2). Point count locations were sampled between a half-hour after sunset and 4 h and surveyed three times throughout the spring and summer (mid-April through late June 2015) in order to detect different anuran species as they become active after hibernation. Visits were separated by at least 15 days and when minimum overnight temperatures were met for each visit (first: 5°C, second: 10°C, and third: 17°C). Surveys were conducted during relatively good weather conditions with minimal wind and precipitation. Basic weather information (e.g., cloud cover, wind), air and standing water temperatures, start time, compass bearing, noise level, and geospatial coordinates of point count locations were recorded at each survey.

Six UW-Green Bay students (advanced undergraduates or graduates) were trained on how to conduct anuran surveys on 23 and 26 March 2015. For safety purposes, surveys were conducted by a team of two students, in which one student conducted the survey itself and the other student collected basic weather information, helped with navigation, and collected geospatial coordinates of the point count locations. Students who conducted the anuran surveys were also required to pass the rigorous certification test, as is done for the CWMP (see QAPP section "Personnel, Special Training Requirements, or Certifications").

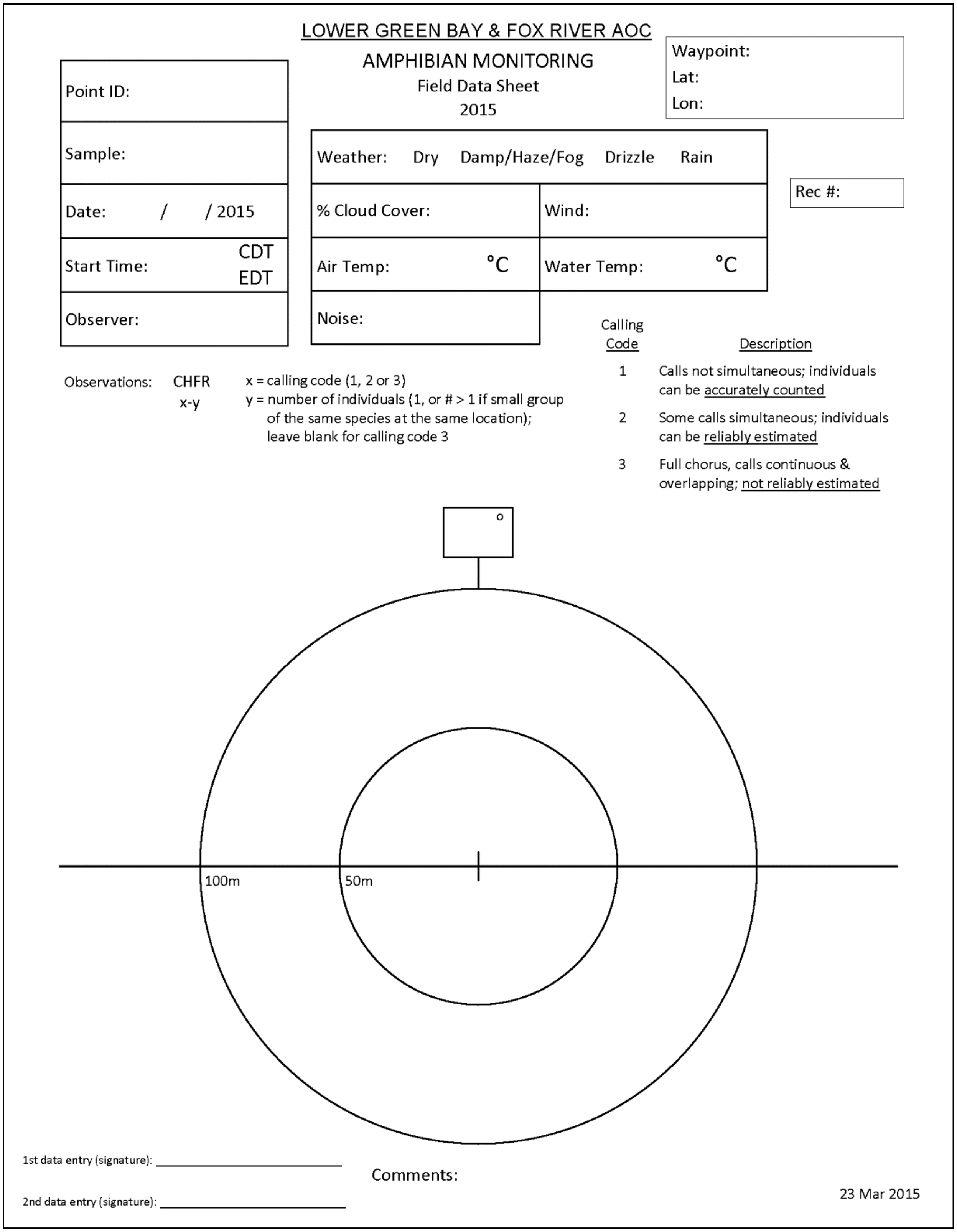
Data Entry

After the field season, two UW-Green Bay students double entered anuran data into a MS Excel spreadsheet created by Giese that employed data validation techniques to minimize data entry error; the two entries were subsequently compared to produce a final, high quality data set (see "Data Management" for more details on data entry). Accompanying metadata were later added.



Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Figure 1. Point count locations (n = 13) positioned in open wetlands primarily dominated by herbaceous plants that were surveyed for anurans (frogs/toads only) in the spring and summer of 2015. They are located within 1 km of shoreline at Lake Michigan/Green Bay high water level of 177.2 m AMSL in the Lower Green Bay and Fox River Area of Concern (AOC) in Wisconsin. Note that one point is located just slightly outside this 1 km buffer in the village of Allouez (~100 m). Basemap sources: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community. Map created in ArcGIS 10.5 (Environmental Systems Research Institute 2016).



LOWER GREEN BAY & FOX RIVER AOC

AMPHIBIAN MONITORING

Field Data Sheet

2015

Waypoint:
Lat:
Lon:

Point ID:

Sample:

Date: / / 2015

Start Time: CDT EDT

Observer:

Weather: Dry Damp/Haze/Fog Drizzle Rain

% Cloud Cover:

Wind:

Air Temp: °C

Water Temp: °C

Noise:

Rec #:

Observations: CHFR x-y

x = calling code (1, 2 or 3)
y = number of individuals (1, or # > 1 if small group of the same species at the same location); leave blank for calling code 3

Calling Code	Description
1	Calls not simultaneous; individuals can be accurately counted
2	Some calls simultaneous; individuals can be reliably estimated
3	Full chorus, calls continuous & overlapping; not reliably estimated

1st data entry (signature): ____________________

2nd data entry (signature): ____________________

Comments:

23 Mar 2015

Figure 2. Sample anuran point count data sheet modified from the Great Lakes Coastal Wetland Monitoring Program (Great Lakes Coastal Wetlands Consortium 2014, p. 141, Uzarski et al. 2017) that was used for spring and summer 2015 field surveys in the Lower Green Bay and Fox River Area of Concern (AOC).

Appendix 3: Habitat Mapping (2015) Methodology

Habitat Classification

In order to assess the current habitat conditions of the LGB&FR AOC, we launched a habitat mapping effort in July 2015 that combined field ground-truthing with the use of satellite imagery and other reference maps in order to identify and map the primary plant communities.

An initial habitat classification used air photos and infrared imagery to distinguish residential and other highly urbanized or industrialized lands ("Developed") and cultivated land ("Agricultural") from all other categories. Mapped non-habitat polygons (Developed and Agricultural lands) were excluded from the subsequent habitat analysis.

Plant communities described in the Wisconsin Wildlife Action Plan (WWAP; 2015) formed the basis of habitat classification (Table 1, Appendix 3). Nineteen habitat types occur within the LGB&FR AOC. Howe, Wolf, and Giese, in consultation with TNC staff and GIS specialist Michael Stiefvater, modified and expanded these categories to account for highly degraded habitat types, which are relatively common in the LGB&FR AOC (Table 1, Appendix 3). Specifically, we:

- Added a plant community type "other forest" in order to distinguish pine plantations and early successional forest (e.g., young forest including dominants like aspen [*Populus* spp.], box elder [*Acer negundo* L.], etc.) from more mature, high quality forest (e.g., northern mesic forest).
- Added plant community type "wasteland" to distinguish highly disturbed industrial lands that are dominated by exotic grasses and forbs (including invasive *Phragmites australis* [Cav.] Steud) from other types like "surrogate grassland."
- Subdivided two original WWAP plant community types into finer categories to better distinguish important habitat types in the LGB&FR AOC. Specifically, we subdivided "emergent marsh" into emergent marsh "high energy coastal" (emergent marsh located along a Great Lakes shoreline that is subject to wave energy and fluctuating water levels), "inland" (emergent marsh located inland that is disconnected from a Great Lake), "riparian" (emergent marsh found alongside a stream), and "roadside" (emergent marsh that occurs in places like roadside ditches).
- Partitioned "surrogate grassland" into three finer divisions: "old field" (open, dry, non-forested area dominated by grasses and/or small shrubs), "restored" (open, dry, non-forested area that was restored to native grasses), and "roadside" (open, dry, non-forested area that occurs along highways and other roads).
- Added category "open water inland" (e.g., lake or pond) and "open water" (bay of Green Bay).

All plant communities listed in Table 1 (Appendix 3) were used during the fieldwork effort, except "emergent marsh roadside," "inland open water," "open water," "Fox River open water," "tributary open water," and "surrogate grassland roadside," which were later added during the digitization process (see "GIS Mapping") to further refine the main categories. All of these modifications improved the co-PIs and Giese's abilities to assess current habitat conditions, identify potentially restorable habitat, and distinguish between areas of lower habitat quality (e.g., "emergent marsh roadside") from potentially higher habitat quality (e.g., "emergent marsh high energy"). If needed, these finer subdivisions and additions can always be combined into the original WWAP categories (e.g., number of hectares of habitat types "surrogate grassland old field," "surrogate grassland restored," and "surrogate grassland roadside" could be combined and reclassified as the original category "surrogate grassland"). Note that "floodplain forest" (FLFO) was listed as a possible habitat that occurs in the LGB&FR AOC but was later determined after the 2015 field work that it does not occur in this area; therefore, this habitat is not included in Table 1 (Appendix 3).

Table 1. Plant communities found within the Lower Green Bay and Fox River Area of Concern that were used for the 2015 habitat mapping effort. Community types and descriptions originated from the Wisconsin Wildlife Action Plan (WWAP; 2015); however, two communities (emergent marsh and surrogate grassland) were subdivided into more detailed categories[1], several communities or subdivisions were added for the field work that were not included in the original WWAP[2], others were added after the field work[3], and some descriptions were modified to better describe each type within this AOC. Scientific names of each common name provided below as a table footnote ‡.

Plant Community Type	Habitat Code	Description
Emergent Marsh[1,2] (High Energy Coastal)	EMHE	Open wetland with standing water in some part of area, dominated by emergent macrophytes. Dominants include cattails, bulrushes, bur-reeds, arrowheads, spikerush, etc.; often invaded by *Phragmites* or reed canary grass. Common in AOC.
Emergent Marsh[1,2] (Inland)	EMIN	
Emergent Marsh[1,2] (Riparian)	EMRI	
Emergent Marsh[1,2,3] (Roadside)	EMRS	
Fox River Open Water[2,3]	FOXR	Open water of the Fox River.
Great Lakes Beach	GLBE	Shoreline habitat at interface of land and water along the margins of Lakes Michigan. Common in AOC. Includes sand, shells, mud, cobble, riprap, vegetation.
Hardwood Swamp	HASW	Wet forest dominated by green or black ash, sometimes with red maple, yellow birch, cottonwood, swamp white oak, and elm. Very common in AOC.
Northern Mesic Forest	NMFO	Widespread forest type dominated or co-dominated by sugar maple, eastern hemlock, white pine, and American beech can be a co-dominant. Other important tree species include yellow birch, American basswood, and white/green ash. Fairly common in AOC.
Open Water Inland[2,3]	OWIN	Inland open water bodies (e.g., retention pond, small lake). Common in AOC.
Green Bay Open Water[2,3]	GBAY	Open water of the bay of Green Bay (i.e., pelagic zone).
Other Forest[2]	OTFO	Broad category meant to capture forest types that don’t fit into other communities. Early successional forests dominated by aspen, box elder, cottonwood, sumac, and young trees of mixed composition. Pine plantations. Very common in AOC.

Submergent Marsh	SUMA	Herbaceous community of aquatic macrophytes in lakes, ponds, and rivers. Dominants include pondweeds along with waterweed, eelgrass, and species of water-milfoil and bladderworts. Somewhat common in AOC.
Shrub Carr	SHCA	Transitional habitat between open wetlands and forested wetlands. Dominated by tall shrubs such as red-osier dogwood, silky dogwood, meadowsweet, and various willows. Canada blue-joint grass is often very common. Common in AOC.
Southern Dry Mesic Forest	SDMF	Forest dominated by red oak, white oak, basswood, sugar and red maple; white ash and shagbark hickory often also present. Relatively uncommon in AOC.
Southern Sedge Meadow	SSME	Open wetland community most typically dominated by tussock sedge and Canada blue-joint grass. Not common in AOC.
Surrogate Grassland[1] (Old Field)	SGOF	Variety of open, non-forested habitats dominated by grasses or upland shrubs. Very common in AOC.
Surrogate Grassland (Restored)[1,2]	SGRE	Variety of open non-forested habitats dominated by native grasses or shrubs. Uncommon in AOC.
Surrogate Grassland (Roadside)[1,2,3]	SGRS	Variety of open non-forested habitats dominated by grasses or shrubs found along roadsides. Very common in AOC.
Tributary Open Water[2,3]	TRIB	Open water of a tributary (e.g., Duck Creek, Mahon Creek).
Wasteland[2]	WAST	Highly disturbed industrial lands dominated by non-native grasses and forbs (e.g., *Phragmites australis*), including the occasional tree/shrub. Common in AOC.

‡ Scientific names of common names listed in Table 1 above are provided alphabetically as follows: American basswood (*Tilia americana* L), American beech (*Fagus grandifolia* Ehrh.), balsam fir (*Abies balsamea* [L.] Mill.), black ash (*Fraxinus nigra* Marshall), bladderworts (*Utricularia* spp.), bur oak (*Quercus macrocarpa* Michx.), Canada blue-joint grass (*Calamagrostis canadensis* [Michx.] P. Beauv.), eastern hemlock (*Tsuga canadensis* [L.] Carrière), eel-grass (*Vallisneria americana* Michx.), elm (*Ulmus* spp.), meadowsweet (*Spiraea alba* Du Roi), northern white cedar (*Thuja occidentalis* L.), pondweeds (*Potamogeton* spp.), red maple (*Acer rubrum* L.), red oak (*Quercus rubra* L.), red-osier dogwood (*Cornus sericea* L.), shagbark hickory (*Carya ovata* [Mill.] K. Koch), silky dogwood (*Cornus amomum* Mill.), spruces (*Picea* spp.), sugar maple (*Acer saccharum* Marshall), sumac (*Rhus* spp.), tussock sedge (*Carex aquatilis* Wahlenb.), water-milfoil (*Myriophyllum spicatum* L.), waterweed (*Elodea canadensis* Michx.), white ash (*Fraxinus americana* L.), white oak (*Quercus alba* L.), white pine (*Pinus strobus* L.), willows (*Salix* spp.), and yellow birch (*Betula alleghaniensis* Britton)

Field Work Planning

To organize and distribute the habitat mapping field work, Howe, Wolf, and Giese divided the study area (LGB&FR AOC boundary plus 1 km of shoreline at Lake Michigan/Green Bay high water level of 177.2 m AMSL) into three general areas (east shore [E], Fox River [F], and west shore [W]) and then divided each area into 44 regions: eight regions on the east shore (E1, …, E8), 17 regions on the Fox River (F1, …, F17), and 19 regions on the west region (W1, …, W19; Figure 1, Appendix 3). To identify and map plant communities directly onto paper maps in the field, they created sub-region maps (n = 197), which presented a closer, more detailed view of each of these regions. Each sub-region map was assigned a name starting with the region name (e.g., F9) followed by a lowercase letter (a, b, c, …, z). For example, map “W1” (which features the western shoreline of the mouth of the Fox River in lower Green Bay) was subdivided into two sub-region maps, W1a and W1b (Figure 2, Appendix 3). All region maps were scaled the same at 500 m, and each sub-region map was scaled at 250 m. Both map types were set to dimensions 1,280 x 720 pixels and printed on 8.5” x 11” paper. In addition to these region and sub-region maps, Stiefvater and two UW-Green Bay students also created two reference maps (printed on 24” x 16” paper) per region (excluding a few Fox River regions) in the field: a) region map that displayed basic property information and Wisconsin Wetland Inventory polygons and associated wetland types (Figure 3A, Appendix 3) and b) region map showing false color infrared imagery, which helps to distinguish different vegetation types (Figure 3B, Appendix 3). These reference maps, particularly region maps displaying Wisconsin Wetland Inventory polygons, were used as starting points for field crews to use when identifying plant communities in the field.

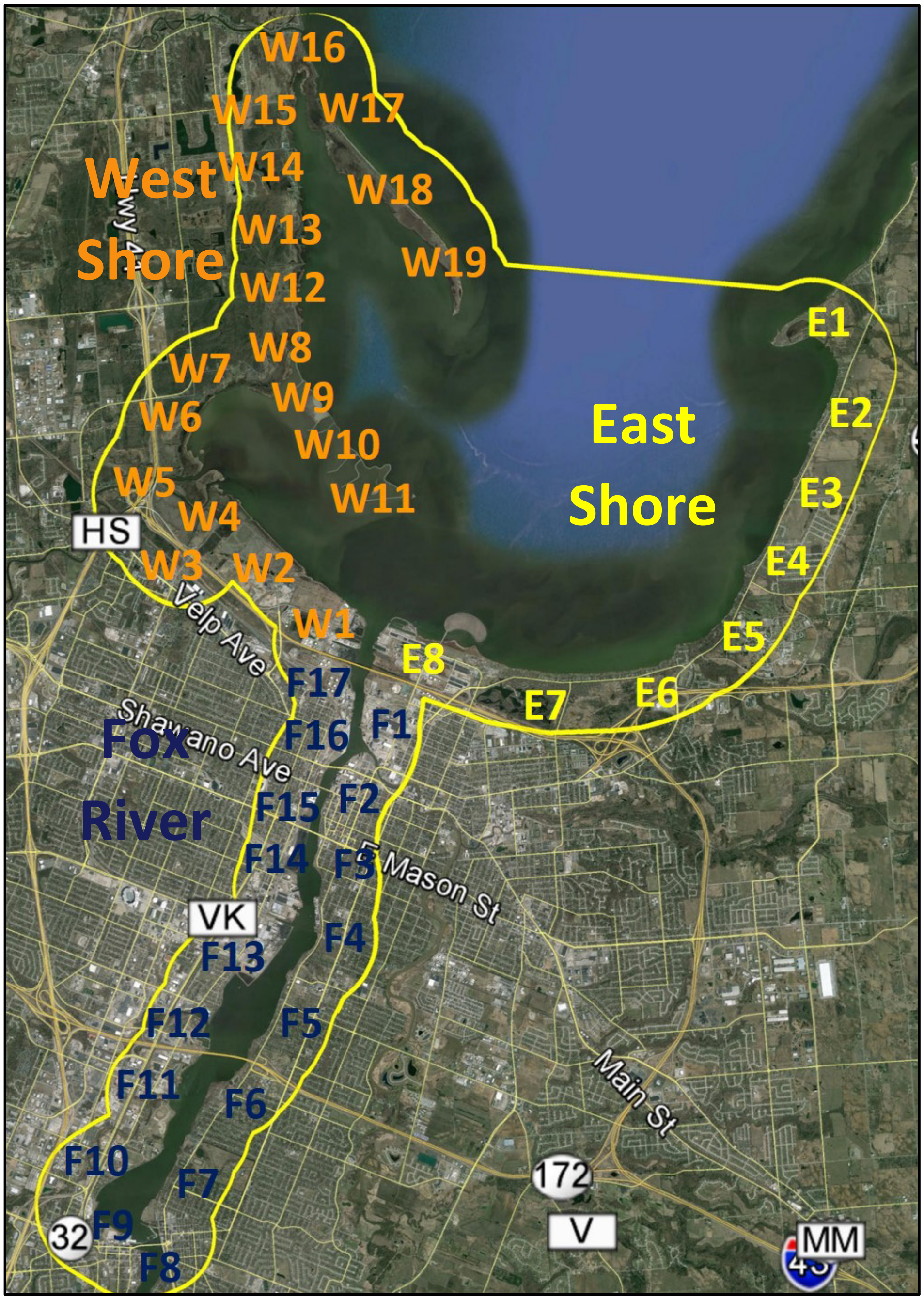


Figure 1. Map of the study area (Lower Green Bay and Fox River Area of Concern boundary plus 1 km of shoreline at Lake Michigan/Green Bay high water level of 177.2 m AMSL; denoted as thick yellow line) that was divided into three areas, the east shore (yellow text), Fox River (blue text), and west shore (orange text), and 44 regions (e.g., E1, …, E8; F1, …, F17; and W1, …, W19) for the July 2015 habitat mapping effort. Satellite imagery shown is from Google Earth (map data: Google, NOAA; imagery date: 13 April 2015; access date: 3 July 2015). Map created using Google Earth Pro.

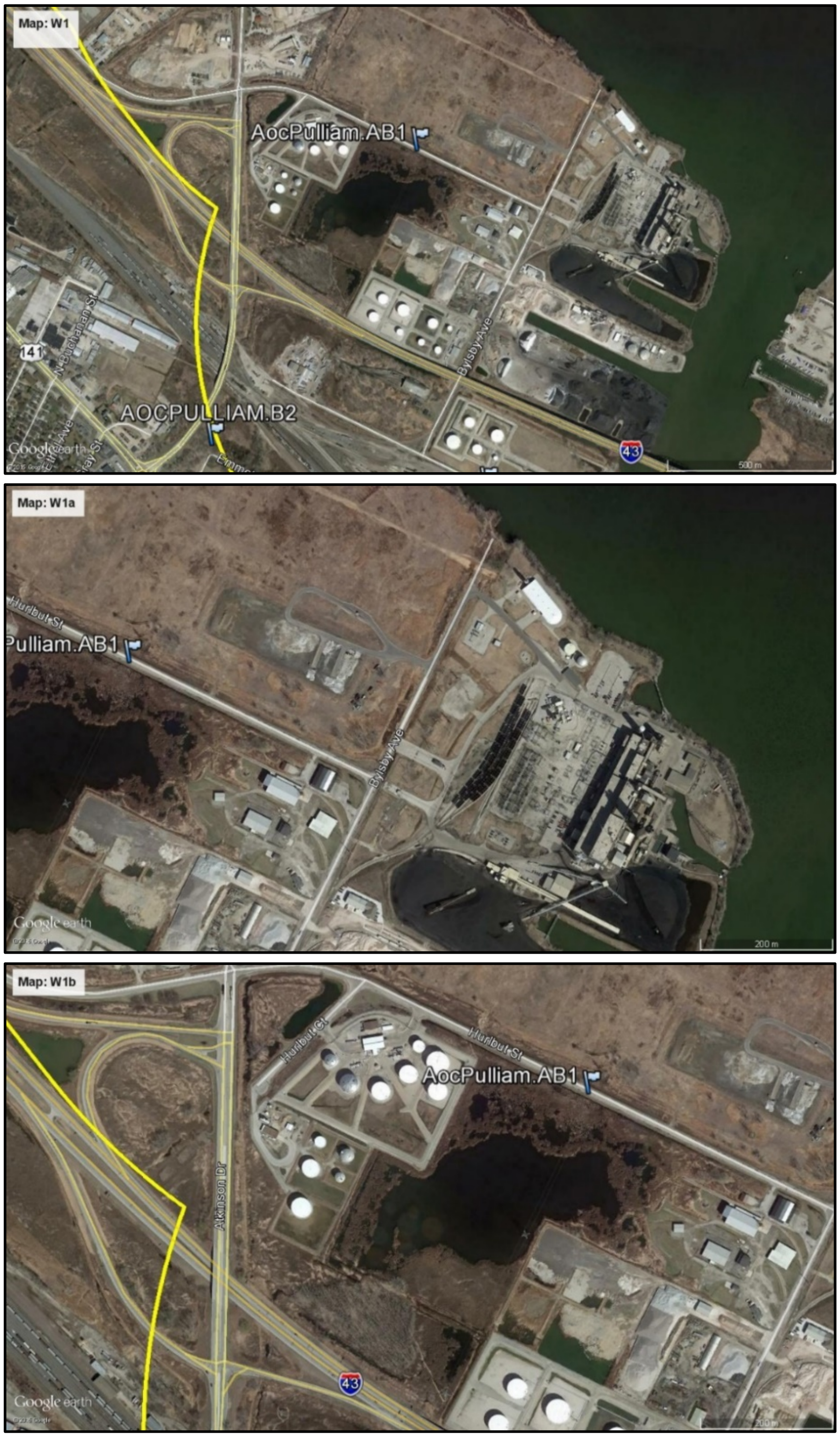


Figure 2. Sample field maps used to identify and map habitat types during the July 2015 field work effort, including a sample region map (W1) and two sub-region maps (W1a and W1b). Field teams drew habitat types by hand directly onto each sub-region map. Anuran and bird point count locations (e.g., AocPulliam.AB1) were added to these maps and uploaded into field teams' GPS units for reference to easily identify accessible locations. Note there is some overlap across sub-region maps as shown in the example above. Habitat types were only identified and mapped on just one of the sub-region maps if maps overlapped. The thick yellow arc indicates the 1 km buffer around the official LGB&FR AOC boundary. Region and sub-region maps were created in Google Earth Pro using Google Earth satellite imagery (map data: Google; imagery date: 13 April 2015; access date: 2 July 2015).

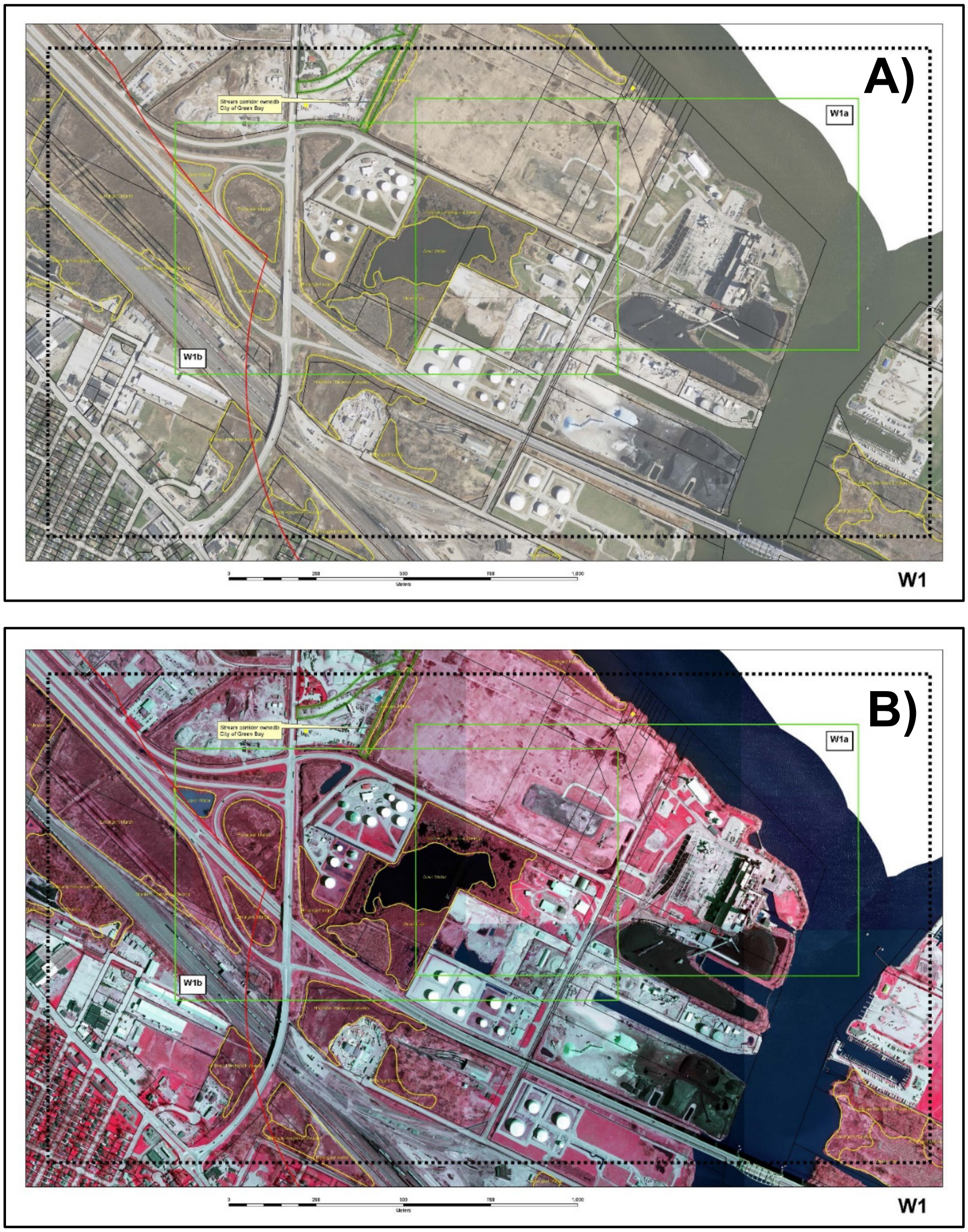


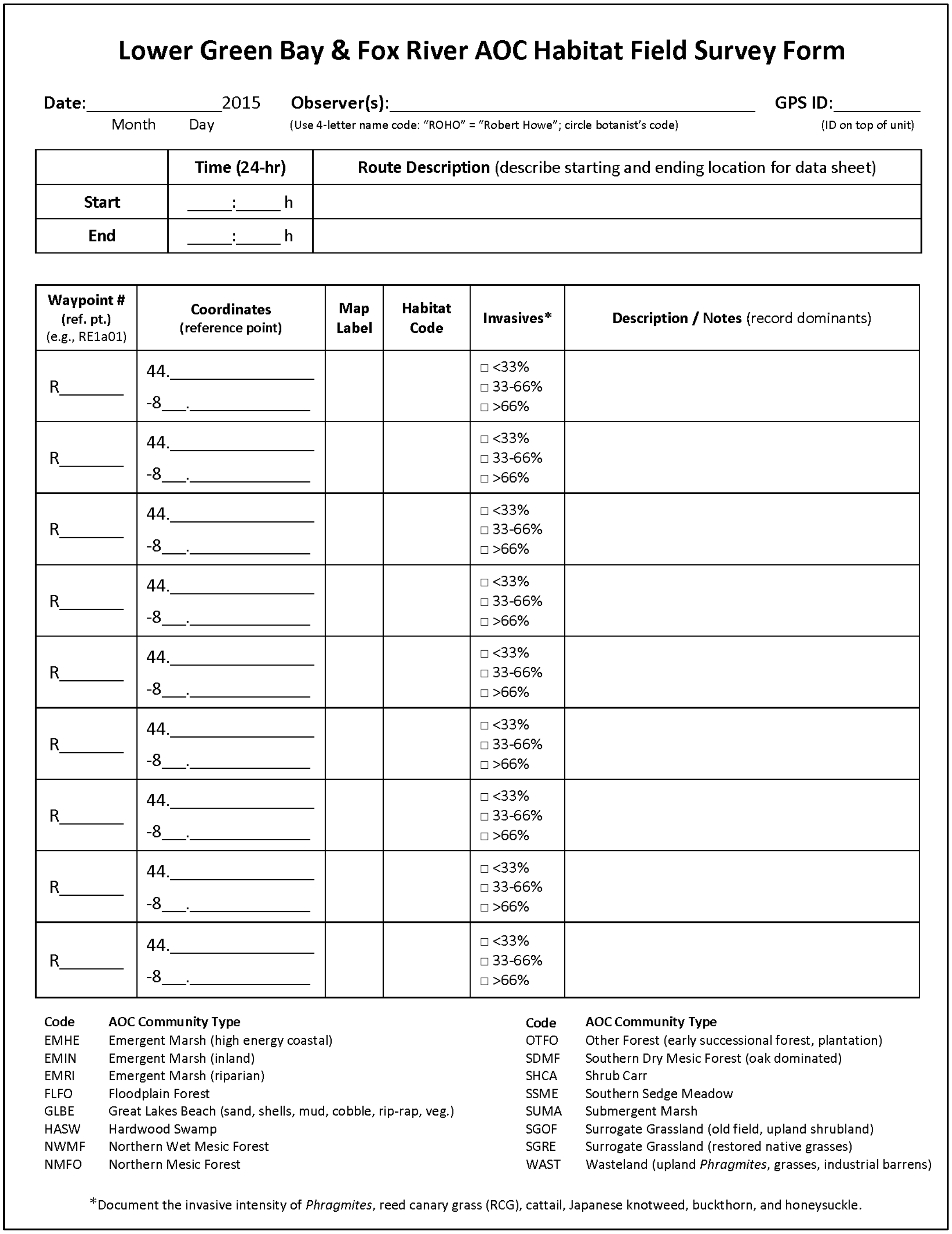
Figure 3. Sample reference maps used in the field during the July 2015 habitat mapping effort: A) aerial photography (dated May 2014) that shows basic property boundaries and Wisconsin Wetland Inventory polygons and wetland types and B) false color infrared imagery (dated May 2014) that distinguishes changes in vegetation; dark red signifies conifers and broad-leaf trees/vegetation (e.g., deciduous tree), light red signifies sparsely vegetated areas (e.g., grass), and dark blue signifies water. Region map boundaries (e.g., W1) shown as a black dotted line. Sub-region map boundaries (e.g., W1a, W1b) denoted as solid green lines. Reference maps were produced by Michael Stiefvater and two UW-Green Bay students using ArcGIS 10.3 software (Environmental Systems Research Institute 2015).

Before the field work, Wolf and Giese next identified locations that they wanted field teams to visit to identify and map plant communities in easily accessible locations (e.g., along a road or trail, public land). Specifically, they examined the satellite imagery displayed on the region and sub-region maps and drew small red dots on areas where the vegetation changed, whether the vegetation was in an isolated patch (e.g., small woodlot) or in a continuous tract of land (e.g., open marsh with a patch of a different habitat type in the middle of the marsh; Figure 4, Appendix 3). They also outlined suggested travel routes via roads or trails using red markers. Field teams were then instructed to visit all locations marked with a red dot on the region/sub-region satellite imagery maps.

Figure 4. Sample map (sub-region F7a; i.e., east side of Fox River in De Pere, Wisconsin by the St. Norbert Abbey) displaying suggested travel routes (red lines) and field locations (red dots) that field teams were instructed to scout and map habitat types during the July 2015 field work effort. The suggested field locations (red dots) were identified prior to the field work and indicate where vegetation changed. Anuran and bird point count locations (e.g., AocAbbey.AB1) were added to these maps and uploaded into field teams' GPS units for reference to easily identify accessible locations. The thick yellow arc indicates the 1 km buffer around the official LGB&FR AOC boundary. Sub-region maps were created in Google Earth Pro using Google Earth satellite imagery (map data: Google; imagery date: 13 April 2015; access date: 2 July 2015).

Field Work Logistics

Field teams consisted of at least three people each filling one of three roles: 1) field crew leader, 2) mapper/navigator, and 3) photographer. Each field team visited every previously identified site location (previously identified as described above) for each sub-region map. The field crew leader's job was to identify and map the major plant communities at each of the site locations. All field crew leaders have extensive knowledge and previous experience at identifying dominant trees, shrubs, and invasive species (e.g., *Phragmites australis*) and a good understanding of the major plant communities in northeastern Wisconsin. Field crew leaders also filled out the accompanying habitat data form (Figure 5, Appendix 3) recording the dominant tree and shrub species and invasive species. The mapper/navigator's responsibilities were to navigate to each location as well as mark reference waypoints with a GPS unit. The photographer was in charge of documenting the major habitat types at each reference waypoint with photographs and filled out the accompanying photograph data form (Figure 6, Appendix 3).



Lower Green Bay & Fox River AOC Habitat Field Survey Form

Date:_______________2015 **Observer(s):**____ **GPS ID:**_________
Month Day (Use 4-letter name code: "ROHO" = "Robert Howe"; circle botanist's code) (ID on top of unit)

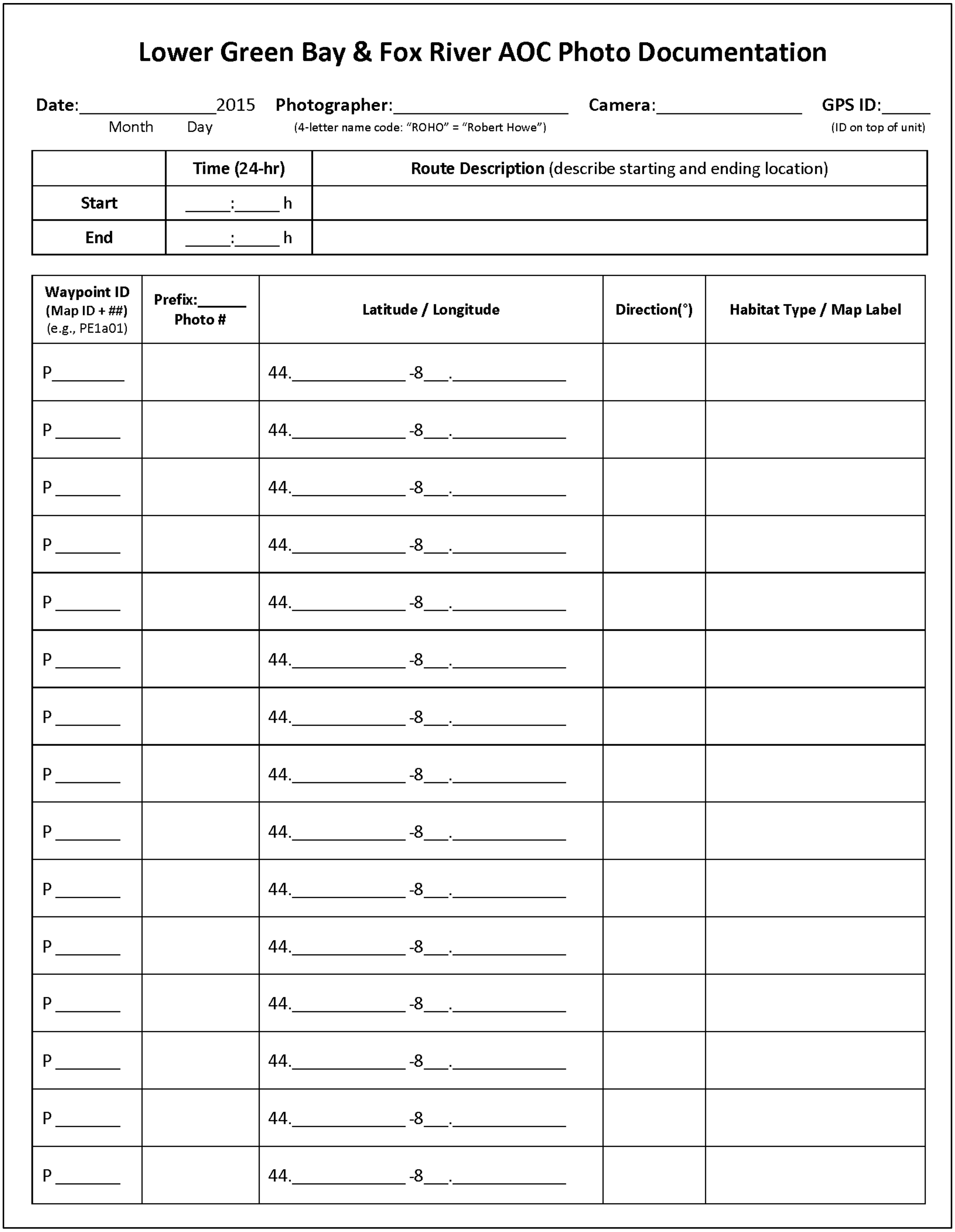
	Time (24-hr)	**Route Description** (describe starting and ending location for data sheet)
Start	_____:_____ h	
End	_____:_____ h	

Waypoint # (ref. pt.) (e.g., RE1a01)	**Coordinates** (reference point)	**Map Label**	**Habitat Code**	**Invasives***	**Description / Notes** (record dominants)
R_______	44._______________ -8___._____________			☐ <33% ☐ 33-66% ☐ >66%	
R_______	44._______________ -8___._____________			☐ <33% ☐ 33-66% ☐ >66%	
R_______	44._______________ -8___._____________			☐ <33% ☐ 33-66% ☐ >66%	
R_______	44._______________ -8___._____________			☐ <33% ☐ 33-66% ☐ >66%	
R_______	44._______________ -8___._____________			☐ <33% ☐ 33-66% ☐ >66%	
R_______	44._______________ -8___._____________			☐ <33% ☐ 33-66% ☐ >66%	
R_______	44._______________ -8___._____________			☐ <33% ☐ 33-66% ☐ >66%	
R_______	44._______________ -8___._____________			☐ <33% ☐ 33-66% ☐ >66%	
R_______	44._______________ -8___._____________			☐ <33% ☐ 33-66% ☐ >66%	

Code	**AOC Community Type**	**Code**	**AOC Community Type**
EMHE	Emergent Marsh (high energy coastal)	OTFO	Other Forest (early successional forest, plantation)
EMIN	Emergent Marsh (inland)	SDMF	Southern Dry Mesic Forest (oak dominated)
EMRI	Emergent Marsh (riparian)	SHCA	Shrub Carr
FLFO	Floodplain Forest	SSME	Southern Sedge Meadow
GLBE	Great Lakes Beach (sand, shells, mud, cobble, rip-rap, veg.)	SUMA	Submergent Marsh
HASW	Hardwood Swamp	SGOF	Surrogate Grassland (old field, upland shrubland)
NWMF	Northern Wet Mesic Forest	SGRE	Surrogate Grassland (restored native grasses)
NMFO	Northern Mesic Forest	WAST	Wasteland (upland *Phragmites*, grasses, industrial barrens)

*Document the invasive intensity of *Phragmites*, reed canary grass (RCG), cattail, Japanese knotweed, buckthorn, and honeysuckle.

Figure 5. Sample habitat data sheet designed by Robert Howe, Amy Wolf, and Erin Giese that was used for the July 2015 habitat mapping effort. Note that several community types (e.g., emergent marsh-roadside, tributary open water) were added after the field work was completed during the digitization process, which is why these categories are not listed at the bottom of the data form.



Lower Green Bay & Fox River AOC Photo Documentation

Date:_______________2015 **Photographer:**__________________ **Camera:**________________ **GPS ID:**_____
Month Day (4-letter name code: "ROHO" = "Robert Howe") (ID on top of unit)

	Time (24-hr)	**Route Description** (describe starting and ending location)
Start	_____:_____ h	
End	_____:_____ h	

Waypoint ID (Map ID + ##) (e.g., PE1a01)	**Prefix:______ Photo #**	**Latitude / Longitude**	**Direction(°)**	**Habitat Type / Map Label**
P________		44.____________ -8___.____________		
P _______		44.____________ -8___.____________		
P _______		44.____________ -8___.____________		
P _______		44.____________ -8___.____________		
P _______		44.____________ -8___.____________		
P _______		44.____________ -8___.____________		
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P _______		44.____________ -8___.____________		

Figure 6. Sample photograph data sheet designed by Robert Howe, Amy Wolf, and Erin Giese that was used for the July 2015 habitat mapping effort.

Wolf, Howe, and Giese distributed field effort by dividing up field teams across the study area by region (east shore, west shore, and Fox River; Figure 1, Appendix 3). At each previously identified site location (marked as red dots on paper maps), field crew leaders first identified the dominant woody vegetation (in field "Description / Notes"), then determined the plant community type (in field "Habitat Code"; e.g., "hardwood swamp" = "HASW"), and finally assessed the intensity of the following invasive plant species: *Phragmites australis* (common reed), reed canary grass, cattail (*Typha x glauca* Godr.), Japanese knotweed (*Fallopia japonica* [Houtt.] Ronse Decr.), buckthorn (*Frangula alnus* Mill. and *Rhamnus cathartica* L.), and honeysuckle (*Lonicera* spp.) using one of three percentage estimates: < 33%, 33-66%, and > 66% (see sample habitat data sheet in see Figure 5, Appendix 3). To keep field documentation simple, other slightly less widespread and less well-known invasive plant species (e.g., spotted knapweed; *Centaurea stoebe* L.) were not included in this invasive intensity estimate but were sometimes noted in the "Description/Notes" field. The navigator/mapper marked a habitat reference waypoint (in field "Waypoint # [ref. pt.]") using his or her GPS unit to geotag where the field crew leader determined the plant community type. Habitat reference points were named using this schematic: starting with the letter "R" ("R" = reference), followed by the sub-region map name (e.g., F7a, E1a), and ending with an incremental two-digit number (including padded zeros). For example, the first habitat reference waypoint taken in sub-region map W3a was called "RW3a01." Each habitat reference waypoint was marked on the habitat data form (Figure 5, Appendix 3), written directly on the associated sub-region map (Figure 7, Appendix 3), and saved to the mapper/navigator's GPS unit. The field crew leader also recorded this habitat reference waypoint and associated geospatial coordinates directly on the habitat data form as a "back-up" in case the information was not saved on the GPS unit. To better distinguish habitat codes drawn on the sub-region maps, the field crew leader also assigned a one- or two-digit number called "map label" and recorded it on the habitat data form. Lastly, for each new habitat data form, field effort and general information were recorded at the top, including date, observers, field crew leader (or "botanist"; using a 4-letter name code consisting of the first two letters of the first name and the first two letters of the last name; e.g., "AMWO" = "Amy Wolf"), GPS unit identifier (ID corresponds to the Cofrin Center for Biodiversity's inventory), and start/end times/routes.

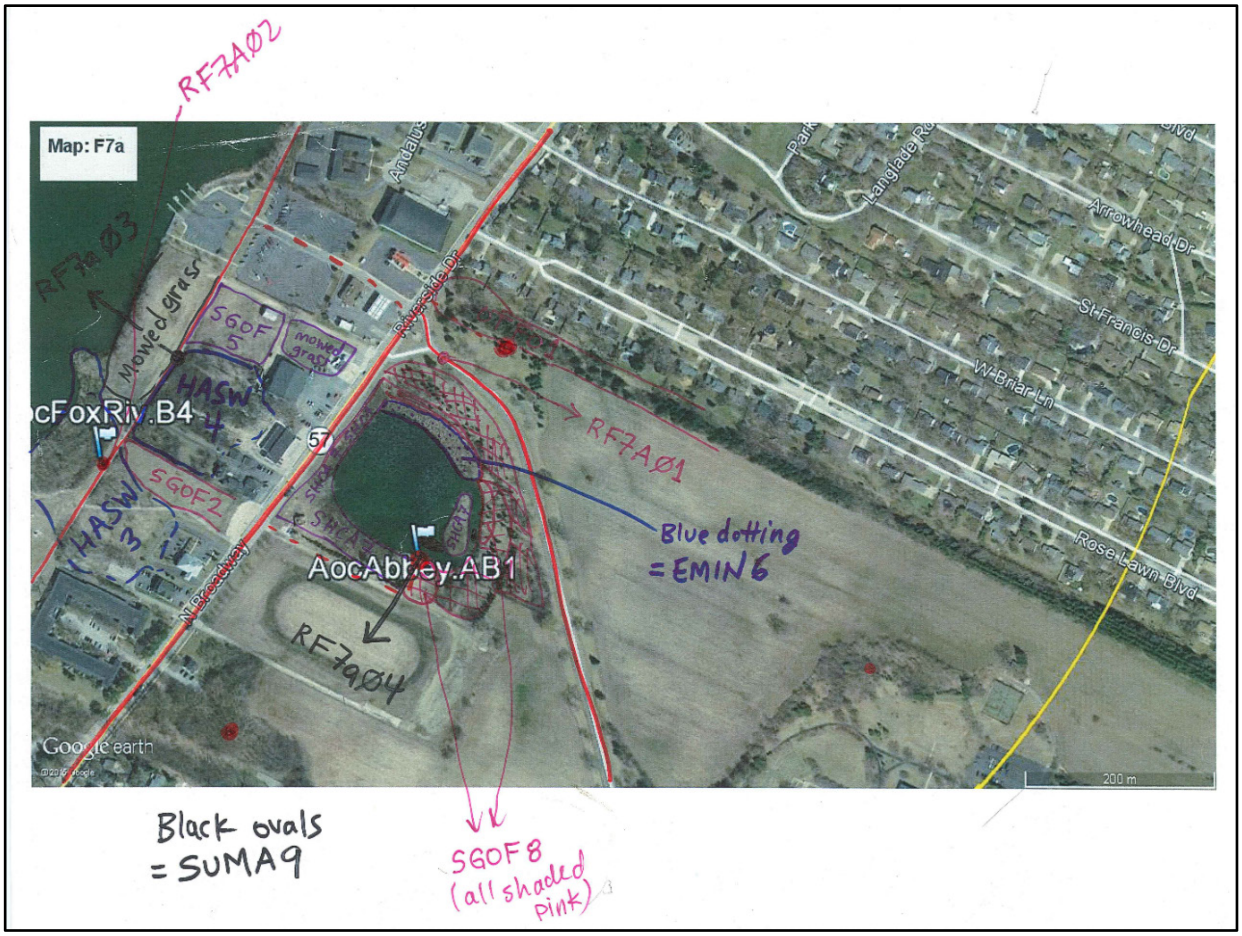


Figure 7. Sample of a completed habitat sub-region map (sub-region F7a; i.e., east side of Fox River in De Pere, Wisconsin by the St. Norbert Abbey) after a field team visited the suggested field locations (red dots) displaying habitat reference waypoints (e.g., RF7a04) and outlined habitat types (if able to do so) and associated map labels (e.g., SGOF8). The suggested field locations (red dots) and travel routes (red lines) were identified prior to the field work and indicate where vegetation appears to change. Anuran and bird point count locations (e.g., AocAbbey.AB1) were added to these maps and uploaded into field teams' GPS units for reference to easily identify accessible locations. The thick yellow arc indicates the 1 km buffer around the official LGB&FR AOC boundary. Sub-region maps were created in Google Earth Pro using Google Earth satellite imagery (map data: Google; imagery date: 13 April 2015; access date: 2 July 2015).

Photo Documentation

At each location field crews visited and mapped habitat types, the photographer crew member took still, digital photographs of the plant communities near the habitat reference waypoints using high end digital cameras; however, new and different waypoints were established called photograph reference waypoints, which geotagged where each photograph was taken. Photograph reference points were named using a similar schematic starting with the letter "P" ("P" = photograph), followed by the sub-region map name (e.g., F7a, E1a), and ending with an incremental two-digit number (including padded zeros). For example, the first photograph reference waypoint taken somewhere in sub-region map W3a was called "PW3a01." Each photograph reference waypoint was marked on the photograph data form (Figure 6, Appendix 3) as well as the photograph file name (in field "Photo #" with associated file name prefix [e.g., "DSC_"]) and saved to the mapper/navigator's GPS unit. Note that photograph reference waypoints are <u>not</u> the same as the habitat reference waypoints despite being named similarly. Photograph waypoints geotagged locations photographs were taken, not necessarily where the field crew leader identified the plant community (i.e., habitat reference waypoint). A compass bearing was taken at each marked photograph reference waypoint to clearly identify the habitat the photograph was documenting. In some cases, for example, the field crew may have been assessing habitat on a road or trail with different habitats on both sides of them; therefore, the compass bearing distinguishes those photographs to avoid confusion. On each photograph data form, field effort and general information were recorded at the top, including date, photographer (using a 4-letter code consisting of the first two letters of the first name and the first two letters of the last name; e.g., “ROHO” = “Robert Howe”), camera (model and identifier [e.g., model, inventory number]), GPS unit ID (ID corresponds to the Cofrin Center for Biodiversity’s inventory), and start/end times/routes.

Field Crew and Training

Including Howe, Wolf, and Giese, 18 field crew members (Table 2, Appendix 3) participated in this habitat mapping field effort. Wolf, Howe, and Giese first led a training for only the field crew leaders on 7 July 2015. Wolf and Howe gave an oral presentation to the crew leaders summarizing the names and descriptions of the main plant communities everyone is likely to encounter during habitat mapping in the LGB&FR AOC. They also highlighted the dominant plants that occur within each plant community as well as presented examples using photographs. After the office training, they took the crew leaders into the field (Point au Sable Nature Preserve) to practice correctly identifying plant communities as a group, estimating the intensity of invasive plants, and filling out the data forms to ensure that all crew leaders were calibrated together. On 8 July 2015, Howe, Wolf, and Giese next led a second training to the remaining students who participated in the habitat mapping effort, including the field crew leaders. In the office they first reviewed the project and field methods of the habitat mapping, including a shortened review of the plant communities. Afterwards, they took the group out in the field (UW-Green Bay Cofrin Memorial Arboretum) to teach the students how to conduct the field work, including marking waypoints, taking photographs, and filling out data forms. Howe, Wolf, and Giese used and saved the data they collected near the lakeshore on the Arboretum as a group as a part of the habitat mapping effort.

Table 2. List of field crew members and their associated roles who participated in the July 2015 habitat field mapping effort. Field crew leaders identified and mapped major plant community types and filled out habitat data forms (Figure 5, Appendix 3) at each site location. Mappers/navigators navigated to each location as well as took habitat and photograph reference waypoints using GPS units. Photographers took still photographs of plant communities identified near habitat reference waypoints and filled out the accompanying photograph data form (Figure 6, Appendix 3). Eight field crew members participated as both the mapper/navigator and photographer.

Name	Role
Erin Giese	field crew leader
Jay Horn	field crew leader
Samantha Nellis	field crew leader
Nick Walton	field crew leader
Bobbie Webster	field crew leader
Amy Wolf	field crew leader
Cody Becker	mapper/navigator
Stephanie Beilke	mapper/navigator
Michael Stiefvater	mapper/navigator
Katie Crews	photographer
Robert Howe	photographer; mapper/navigator
Jason Brabant	photographer; mapper/navigator
Becky DeValk	photographer; mapper/navigator
Abigail Englebert	photographer; mapper/navigator
Chelsea Gunther	photographer; mapper/navigator
Matt Peter	photographer; mapper/navigator
Tom Prestby	photographer; mapper/navigator
Jesse Weinzinger	photographer; mapper/navigator

Six field crew members were field crew leaders, eight participated as both a photographer and mapper/navigator, three crew members participated as the mapper/navigator only, and one crew member played the role of photographer only. Most of the habitat mapping was completed on 13-15 July 2015, though two crews finished mapping remaining areas on 16-17 July 2015. On 30 July 2015, one team operated a small motorized boat to map plant communities along the shorelines of the west and east shorelines. The boat operator was certified by the state of Wisconsin to operate motorized boats, while the others passed the Paddle Sports Safety Course (http://www.boaterexam.com/paddling/), which teaches safety in using canoes, kayaks, and paddleboards. To ensure that all field teams were calibrated and recording data similarly (in terms of habitat assignments and invasive species estimates), Howe, Wolf, and Giese mixed up the field crew members between the first (13 July 2015) and second (14 July 2015) full work days. Meaning, they reassigned one or two field crew members from one team on the first day with a different team on the second day. After the first and second days, field crews also reconvened in the office after field work to discuss and resolve any issues or questions that arose while collecting data. This further ensured that teams were collecting information in the same manner across teams.

Field Data Management and Archiving

Giese designed a system to have crew members back up his or her team's data that were collected in the field that day, including geospatial data (GPS unit) and digital photographs, immediately at the end of each field workday. She trained and provided instructions on how to organize the information properly to individual students and staff. Photographs and geospatial coordinates (saved as .gpx) were saved in individual folders and file names labeled with the team's field crew leader's 4-letter name code (e.g., "AMWO" = "Amy Wolf") and 8-digit calendar date of download ("14 JUL 2015" = "20150714"). Wolf and Giese scanned all data sheets and maps either at the end of a field workday or the next day as back-up copies. Implementing these strict data back-up procedures ensured no data were lost. All habitat and photograph reference waypoints (n = 612) are shown in Figure 8 (Appendix 3).

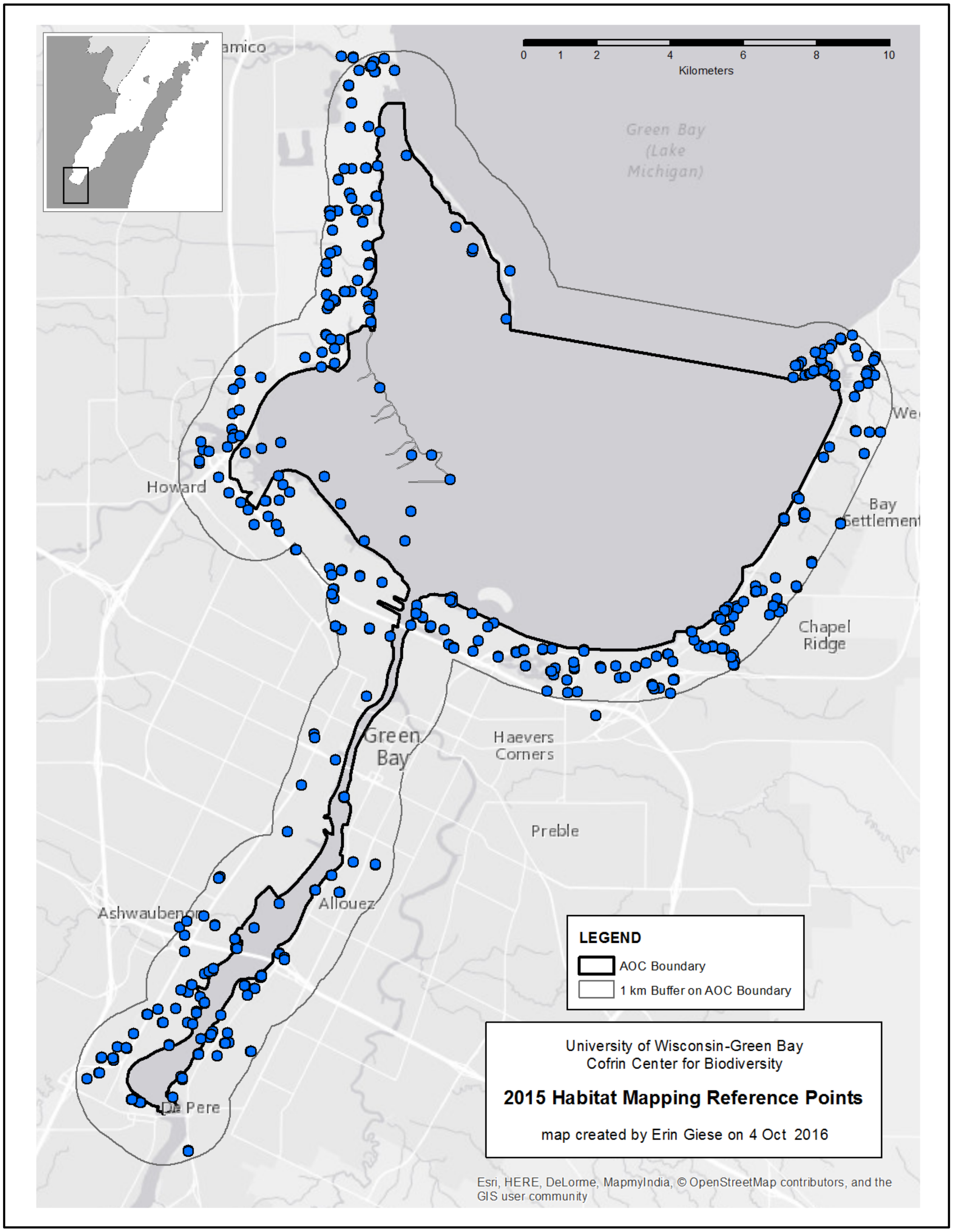


Figure 8. Reference habitat and photograph waypoints (n = 612; 278 habitat waypoints and 334 photograph waypoints) that were visited by field crews to map the main plant communities and document these habitats with digital photographs in July 2015. Habitat and photograph waypoints were displayed using the same symbol because they overlap. They are located close to or within 1 km of shoreline at Lake Michigan/Green Bay high water level of 177.2 m AMSL in the Lower Green Bay and Fox River Area of Concern (AOC) in Wisconsin. Points collected outside the 1 km buffer were used to identify plant communities located within the buffer. Basemap sources include Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community. Map created in ArcGIS 10.3.1 (Environmental Systems Research Institute 2015).

Photograph Processing

After the field season, UW-Green Bay undergraduate student, Sahara Tanner, used MS Photo Gallery to conduct minor edits to the photographs taken of plant community types as needed. For example, some photographs were either underexposed (too dark) or overexposed (too bright); therefore, the student performed minor adjustments using the “Adjust exposure” option in MS Photo Gallery including adjusting brightness or contrast. In most cases, photographs were edited using minor brightness adjustments; however, sometimes the image’s contrast was adjusted to bring out the original image. In all cases, the integrity and reality of the photograph were maintained so that the original or realistic colors of the plant community were not lost or greatly modified. Reference habitat photographs that were geotagged and documented on the field data forms were separated from general field work photographs (e.g., documenting an unidentified plant, picture of a bird, picture of field crew), which were filed into separate folders. The reference habitat photographs and the data that correspond to them (e.g., habitat type, dominant plants) were organized by UW-Green Bay undergraduate student, Jordan Marty, under the guidance of Michael Stiefvater and Giese.

Data Entry

After the field season, the habitat and photograph data were double entered into MS Excel spreadsheets created by Giese that employed data validation techniques to minimize data entry error (see “Data Management” for more details on data entry). Two undergraduate students, Sahara Tanner and Jeremiah Shrovnal, comprised the first entry; graduate student, Chelsea Gunther, constituted the second entry. Gunther compared the two entries of each data set and gave Giese these two first draft data sets. Giese spent significant time editing, auditing, and correcting additional errors and issues with the data sets, including comparing the collected waypoints saved as .gpx files against the list of waypoints entered from the habitat and photograph data sheets. Corrections were made as needed. Giese wrote accompanying metadata and produced two final, high quality data sets.

Appendix 4: Botanical Survey Methodology of Plant Biodiversity Hotspots (2016)

Purpose

Although the 2015 habitat mapping effort generated a lot of information on plant communities throughout the LGB&FR AOC (Appendix 3), most field visits were short and only the major habitat type and dominant plant species were recorded at each location. Therefore, we launched a second field effort in July 2016, in which they commissioned UW-Green Bay’s Gary A. Fewless Herbarium Curator, James Horn, to conduct more detailed plant surveys in high quality areas. Horn and his team explored and described “plant biodiversity hotspots” that are generally of high quality (i.e., high native plant diversity) and also recorded comprehensive lists of plants that were present in the hotspot area(s) at each site. We deemed 28 of the 55 “priority areas” to be of sufficient botanical interest to warrant a survey. Sites of small area often consisted wholly of a single “plant biodiversity hotspot,” whereas larger sites consisting of a mosaic of several plant community types sometimes contained several “plant biodiversity hotspots.” Especially within several of the more poorly explored larger sites, Horn searched for additional “plant biodiversity hotspots” that were expected to be present or not well characterized based on existing information. Information collected from both the 2015 habitat mapping and 2016 detailed plant surveys provided greatly needed, baseline information on available fish and wildlife habitat within the LGB&FR AOC that will ultimately assist with restoration efforts in the future.

Field Work Planning

After visiting nearly all available habitat in the LGB&FR AOC in 2015, Howe, Wolf, and Giese gained a general sense of which areas contain (or potentially contain) high quality habitat that are worth protecting and restoring. To organize this 2016 field effort, they first identified 55 "priority areas" throughout the study area (LGB&FR AOC boundary plus 1 km of shoreline at Lake Michigan/Green Bay high water level of 177.2 m AMSL), in which a "priority area" is defined as an area of importance that contains available fish and wildlife habitat and that may serve as a type of "management unit" or "focus area" for future restoration planning. Most of these "priority areas" were already previously known to be of particularly high caliber (e.g., west and east shores of the Bay), while others were known to be of lower quality (e.g., sites along the Fox River). They looked across the study area and delineated 55 such areas that were later digitized into an ArcGIS shapefile by UW-Green Bay undergraduate student, Jordan Marty. Horn and two UW-Green Bay students (undergraduate student, Emily Vandersteen, and graduate student, Vanessa Brotske) visited and catalogued 28 of the higher quality "priority areas," for which we wanted more detailed plant information (Table 1, Appendix 4). A few sites along the west and east shores were not visited in 2016 because the crew was either unable to access the site (e.g., St. Francis Tributary) or because the site was already well known (e.g., Keith White Prairie). Nearly all of the Fox River sites were not visited in 2016 because adequate information was already collected in 2015; the 2015 field crew, led by Giese, requested that Horn revisit three Fox River sites to ensure all possible botanical data were recorded, particularly herbaceous plants (e.g., submergent and emergent plants, grasses, etc.). Botanist Kathryn Corio also helped with this 2016 field effort during the early stages of its development and described plant diversity at a few localities.

Table 1. Original “priority areas” (n = 55) within the Lower Green Bay and Fox River Area of Concern in Wisconsin that we identified as areas that contain available fish and wildlife habitat, including some sites that are of particularly high quality. A field crew conducted detailed plant surveys at 28 of these sites in July-September 2016.

Priority Area	General Area	Field Survey in 2016?
Sensiba South	west shore	Yes
Long Tail Point	west shore	Yes
Long Tail Beach Road Hardwood Swamp	west shore	Yes
Dead Horse Bay	west shore	Yes
Barkhausen Waterfowl Preserve	west shore	Yes
Cat Island Chain Restoration Site	west shore	Yes
Fort Howard Wildlife Area	west shore	Yes
Malchow/Olson Tract	west shore	Yes
Peters Marsh	west shore	Yes
Cottage Grove Complex	west shore	Yes
Lakeview Road Hardwood Swamp	west shore	No
Duck Creek Estuary North	west shore	Yes
Duck Creek Estuary South	west shore	Yes
Ken Euers Nature Area	west shore	Yes
Upper Duck Creek North	west shore	Yes
Upper Duck Creek South	west shore	Yes
Railroad Complex	west shore	Yes
WPS/City of Green Bay Complex	west shore	No access
Point Sable	east shore	Yes
Wequiock Creek East	east shore	Yes
St. Francis Tributary	east shore	No access
Barina Parkway	east shore	Yes
Scottwood Creek	east shore	Yes
Mahon Woods and Creek	east shore	Yes
Bay Shore Woods and Beach	east shore	Yes
Keith White Prairie	east shore	No
UWGB Oak Savanna	east shore	No
Bay Beach Wildlife Sanctuary East	east shore	Yes
Bay Beach Wildlife Sanctuary West	east shore	Yes
Bay Beach Amusement Park Shoreline	east shore	Yes
Frigo Bridge Inlet	east shore	No access
Fox River Trail	Fox River	No
Saint Francis Park	Fox River	No
Optimist Point	Fox River	No
Allouez Riverside Park	Fox River	No
Jones Point	Fox River	Yes
Village of Allouez Shoreline Park	Fox River	No
Nicolet Bank Forest	Fox River	No

Priority Site	General Area	Field Survey in 2016?
Abbey Pond	Fox River	Yes
Voyager Park	Fox River	No
Expera Inlet	Fox River	No
Ashwaubomay Park	Fox River	No
Brown County Fairgrounds	Fox River	No
Ashwaubenon Creek	Fox River	No
Bay Harbor Wetland on Fox River	Fox River	Yes
Dutchman Creek	Fox River	No
Frying Pan Shoal/Point Sable Bar	open water	No access
Duck Creek	open water	No
East River	open water	No
Fox River Mouth	open water	No
Fox River	open water	No
Lone Tree and Grassy Island	open water	No
Green Bay Open Water East	open water	No
Green Bay Open Water West	open water	No
Renard Island	open water	No

Field Work Logistics

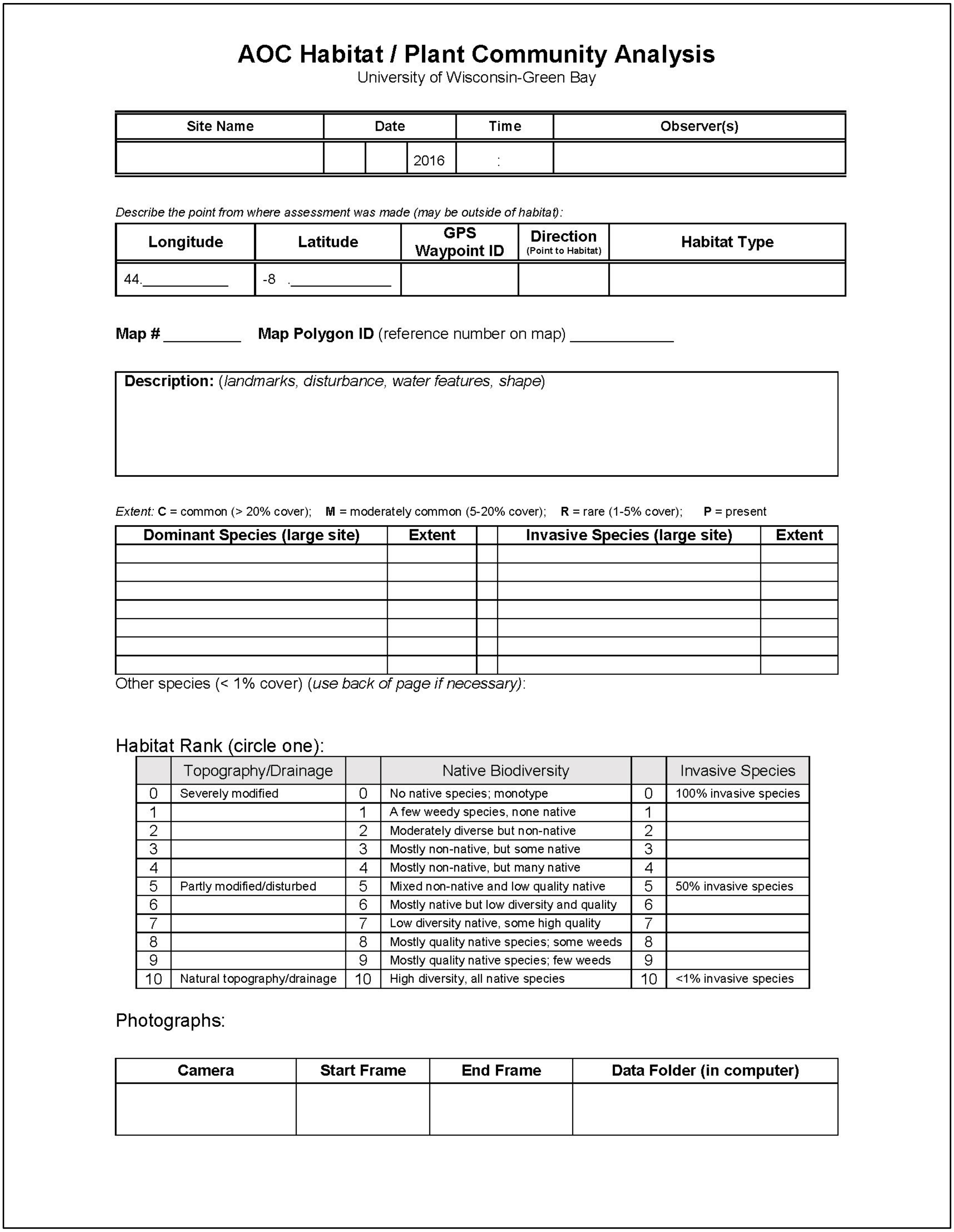
Horn conducted detailed plant surveys with the assistance of one or two UW-Green Bay students (Vandersteen and Brotske). The students helped by assisting with navigating and marking waypoints (documenting their location). Additionally, the crew carried reference maps and previously filled out data forms and maps from the 2015 habitat mapping effort (Appendix 3) to facilitate the 2016 fieldwork.

Upon arriving at one of the 28 sites that were assigned to him, Horn quickly started investigating the site on foot looking for high quality areas in terms of native plant diversity. Once he located such a place, he and his assistants filled out a field data form (Figure 1, Appendix 4). They immediately recorded a reference waypoint and associated geospatial coordinates (saved on a GPS unit and recorded on paper data form) in order to geotag their current location. Each waypoint was named using shortened versions of the general site name and habitat type imbedded in it as abbreviations. For example, Horn visited an emergent marsh at Duck Creek at the Deerfield Docks boat landing at the end of West Deerfield Avenue. He named the reference waypoint as “DCEM01,” in which “DC” stands for “Duck Creek” and “EM” stands for “emergent marsh” at point 01. If additional points were recorded nearby in the same sites and habitat, he used the same site-related naming information but incremented the waypoint numerically (e.g., “DCEM02”).

They recorded basic information like the calendar date, observer(s), site name, and dominant habitat type as well as a general description of the area (e.g., dominant plants, landmarks, disturbance, water features, or shape). The crew also filled out three “habitat ranks,” which describe the habitat quality of the site: a) topography/drainage (describes how the site’s overall landscape drains, whether it drains naturally or artificially through landscape modification), b) native biodiversity (describes the diversity of plants in terms of how many native and/or non-native plants are present), and c) invasive species (quantitative estimate [%] of any invasive species present, unlike the 2015 habitat mapping effort which focused on a small set of target invasives [see “Field Work Logistics” from Appendix 3 for list of target invasives]).

Most importantly, Horn recorded a detailed, comprehensive list of all plants found at any given location, including both native and invasive plants (Figure 1, Appendix 4). For each species recorded, he described how common it was by using an extent code: a) *C*, common (>20% cover), *M*, moderately common (5-20% cover), and *R*, rare (<5% cover). As Horn searched for and documented plant species, his field assistant(s) took additional “trailing waypoints” using the GPS unit’s default waypoint name that is assigned automatically when one marks a waypoint. By looking at the first reference waypoint (e.g., DCEM01) and the “trailing waypoints” (e.g., 165), one can quickly see where the field crew went in terms of documenting plants at a particular site. Horn also collected >500 plant specimens to document the plants he found and recorded specimen-related information into a separate notebook. All plant specimens were subsequently archived at the UW-Green Bay Gary A. Fewless Herbarium.

Some data fields on the paper data form (Figure 1, Appendix 4) were not used throughout the field season because they were later determined to have little added value (e.g., *Map #*, *Time*, *Direction*). They were included in earlier versions of the data form but not regularly used throughout the field season. Although general fieldwork photographs were taken, photographs were not always geotagged at the point-specific level as noted on the data form. Throughout the field season, Horn consulted with Howe, Wolf, and Giese regularly to discuss and resolve any issues or questions that arose.



AOC Habitat / Plant Community Analysis

University of Wisconsin-Green Bay

Site Name	Date			Time	Observer(s)
			2016	:	

Describe the point from where assessment was made (may be outside of habitat):

Longitude	Latitude	GPS Waypoint ID	Direction (Point to Habitat)	Habitat Type
44.___________	-8 ._____________			

Map # _________ **Map Polygon ID** (reference number on map) ____________

Description: (*landmarks, disturbance, water features, shape*)

Extent: **C** = common (> 20% cover); **M** = moderately common (5-20% cover); **R** = rare (1-5% cover); **P** = present

Dominant Species (large site)	Extent		Invasive Species (large site)	Extent

Other species (< 1% cover) (*use back of page if necessary)*:

Habitat Rank (circle one):

	Topography/Drainage		Native Biodiversity		Invasive Species
0	Severely modified	0	No native species; monotype	0	100% invasive species
1		1	A few weedy species, none native	1	
2		2	Moderately diverse but non-native	2	
3		3	Mostly non-native, but some native	3	
4		4	Mostly non-native, but many native	4	
5	Partly modified/disturbed	5	Mixed non-native and low quality native	5	50% invasive species
6		6	Mostly native but low diversity and quality	6	
7		7	Low diversity native, some high quality	7	
8		8	Mostly quality native species; some weeds	8	
9		9	Mostly quality native species; few weeds	9	
10	Natural topography/drainage	10	High diversity, all native species	10	<1% invasive species

Photographs:

Camera	Start Frame	End Frame	Data Folder (in computer)

Figure 1. Sample field data form designed by Robert Howe and Amy Wolf that was used for the 2016 detailed botanical survey effort in the Lower Green Bay and Fox River Area of Concern in Wisconsin. Note that some fields were not regularly used in the field (see text in section “Field Work Logistics” of Appendix 4).

Photo Documentation and Processing

General photographs were taken at some of the sites that the field crew visited, though they were not always geotagged at a point-specific level. The photos were digitally organized into folders based on the photographer's name.

Field Crew and Training

After Wolf and Howe designed the first version of the data form, Wolf went into the field with Kathryn Corio to test the field methods and data form and determine if they should be modified. Then, Corio conducted these detailed botanical surveys at a few sites with Wolf and students early in the field season, which served as a basic training; afterwards, Horn conducted the remaining plant surveys with the student assistants, visiting over half of the "priority areas." Each person collecting field data was either trained individually or as a member of a team.

Field Data Management and Archiving

Giese designed a data management system for organizing and backing up incoming field data, including field data forms, maps, and geospatial data (from GPS unit). At the end of each field day, Vandersteen scanned newly filled out field data forms and filed them into folders labeled using that field day's calendar date. She also scanned and filed maps that contained newly recorded data on them, though maps were only used during the first few field days. She saved geospatial coordinates as .gpx files after each field day and named the files with imbedded metadata like the botanist's four-letter name code (e.g., "JAHO" = "James Horn"), the GPS unit's Cofrin Center for Biodiversity inventory number, and the date the data were downloaded. Implementing these strict data back-up procedures ensured no data were lost.

Data Entry

After the field season, Vandersteen entered the detailed botanical survey data into a MS Excel spreadsheet created by Giese that employed data validation techniques to minimize data entry error. Horn spent significant time editing, auditing, and correcting additional errors and issues with the data set, and Giese compiled and compared the collected waypoints saved as .gpx files against the list of waypoints entered from the plant field data sheets. Corrections were made as needed. Giese wrote accompanying metadata and produced a final, high quality data set.

Appendix 5: Submerged Aquatic Vegetation Surveys (2017)

These surveys were funded under a different GLRI grant than the rest of this report

Field Work

We sampled submerged aquatic vegetation within the LGB&FR AOC between 10 July and 8 August 2017. Sample locations were selected by James Horn and Amy Wolf using recent satellite imagery of the LGB&FR AOC (especially Google Earth image from USDA Farm Service Agency dated 22 June 2008) and direct field observations when beds of vegetation were encountered. We sampled SAV from boats (15-foot Lund or kayaks) using rakes and, when possible, by hand. Each time we encountered a patch of SAV, we documented the species found, relative abundance of each species and GPS location. The field crew attempted to cover most of the shoreline habitat within the LGB&FR AOC (Figure 7b, Appendix 5).

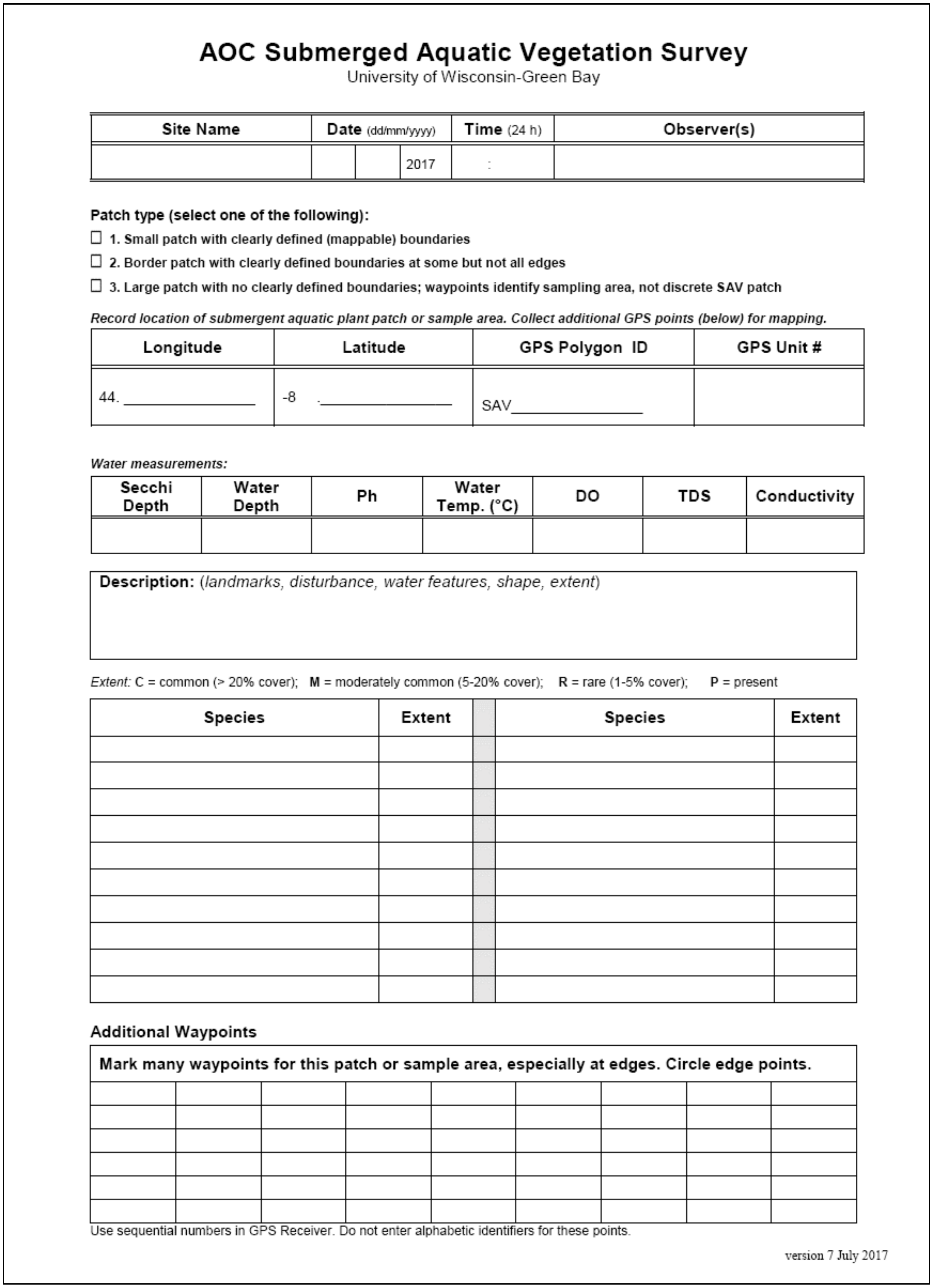
Plants that could be easily identified in the field were recorded on a data form (Figure 1, Appendix 5). Others were collected and placed in labeled (location number and date) plastic zip-lock bags with water. Specimens were separated, identified and processed by Horn at the University of Wisconsin Green Bay Gary A. Fewless Herbarium. Selected specimens for most species are deposited in the Fewless Herbarium collection. We used Skawinski (2014) as the primary taxonomic reference.

Field assistants (Maria Otto and Colton Tanner) collected water chemistry data, recorded geospatial coordinates using a handheld GPS receiver, and completed the data sheets. We collected pH, water temperature, dissolved oxygen (%L and mg/L), TDS (Total dissolved solids), conductivity (uS/cm), SPC (specific conductivity, us/cm), and mmHg (pressure) using a YSI Pro Plus probe at many of the SAV points. Depth and clarity of the water using a secchi disk were also recorded from many of the sample points.

Results

We conducted boat surveys for submerged aquatic vegetation within the Lower Green Bay and Fox River AOC during July and early August 2017. Altogether we recorded 46 aquatic plant species; 7 free-floating (Table 7a, Appendix 5), 4 floating-leaf rooted (Table 7b, Appendix 5), 24 submerged (Table 7c, Appendix 5) and 11 emergent species in submerged form (Table 7d, Appendix 5). Three species of invasive non-native plants were detected (*Myriophyllum spicatum, Najas minor* and *Potamogeton crispus*) (Figure 9, Table 7c, Appendix 5). Detailed descriptions about species abundance and distributions within the AOC are provided in the notes section of tables 7a-7d (Appendix 5). Coefficients of Conservatism (CC value) for Wisconsin plants are provided in the tables below (Wisconsin Floristic Quality Assessment 2017).

Submerged aquatic vegetation was widespread on the west shore extending from Duck Creek to Dead Horse Bay, but sparse and patchy on the east shore with the exception of Point au Sable (Figure 7a, Appendix 5). Several locations stand out as SAV “hotspots” in terms of species diversity, abundance, and high-quality plants (CC values). These include Dead Horse Bay and Duck Creek on the west shore and Point Sable on the east shore (Figures 8a-8c, Appendix 5).



AOC Submerged Aquatic Vegetation Survey

University of Wisconsin-Green Bay

Site Name	Date (dd/mm/yyyy)			Time (24 h)	Observer(s)
			2017	:	

Patch type (select one of the following):

☐ **1. Small patch with clearly defined (mappable) boundaries**

☐ **2. Border patch with clearly defined boundaries at some but not all edges**

☐ **3. Large patch with no clearly defined boundaries; waypoints identify sampling area, not discrete SAV patch**

Record location of submergent aquatic plant patch or sample area. Collect additional GPS points (below) for mapping.

Longitude	Latitude	GPS Polygon ID	GPS Unit #
44. ________________	-8 .________________	SAV________________	

Water measurements:

Secchi Depth	Water Depth	Ph	Water Temp. (°C)	DO	TDS	Conductivity

Description: (*landmarks, disturbance, water features, shape, extent*)

Extent: C = common (> 20% cover); **M** = moderately common (5-20% cover); **R** = rare (1-5% cover); **P** = present

Species	Extent		Species	Extent

Additional Waypoints

Mark many waypoints for this patch or sample area, especially at edges. Circle edge points.

Use sequential numbers in GPS Receiver. Do not enter alphabetic identifiers for these points.

version 7 July 2017

Figure 1. Data form for Submerged Aquatic Vegetation field surveys in the Lower Green Bay and Fox River Area of Concern.

Table 7a. Free-floating submerged aquatic plants observed in Lower Green Bay and Fox River Area of Concern (AOC) during July and August 2017. Coefficient of conservatism values (CC value) for Wisconsin plants (WDNR Floristic Quality Assessment). Notes provide a description of distribution and abundance of each species during the sample period.

Free-floating Plants				
Scientific Name	**Common Name**	**Family**	**CC Value**	**Notes**
Lemna minor	Small duckweed	Araceae	4	A widely distributed species in the AOC, but only common in stagnant backwaters, notably of Wequiock Creek, the lagoon at Point au Sable, and Duck Creek. Present in floating duckweed mats of most areas, where it occurs mixed with the similar-appearing and (typically) much more abundant *Lemna turionifera*. It is very rare or not present at Fox River sites.
Lemna trisulca	Forked duckweed	Araceae	6	A conspicuous, but rarely common, species of quiet waters of higher-quality submerged marshes, notably Dead Horse Bay, Duck Creek, the Cat Island Chain Restoration Site, and Point au Sable. It is absent from Fox River sites. This species forms tangled mats just beneath the water surface.
Lemna turionifera	Turion duckweed	Araceae	2	The most widespread and easily the most abundant duckweed species in the AOC, present in duckweed mats of all areas.
Riccia fluitans	Slender riccia	Ricciaceae (complex-thallose liverwort)	—	An overall rare species in the AOC, locally moderately common only in Dead Horse Bay. It is also present in the Point au Sable lagoon and the Cat Island Chain Restoration Site (near Peters Marsh), where it occurs in very low (rare) abundance. This species floats just beneath the water surface, typically tangled in mats of *Lemna trisulca*.
Spirodela polyrrhiza	Great duckweed	Araceae	5	A commonly encountered species throughout the AOC that is present in very rare to common abundance in duckweed mats of all but the most stagnant waters.

Wolffia borealis	Northern watermeal	Araceae	6	The rarest and least abundant duckweed species in the AOC. It is most readily encountered in still, but not stagnant, backwaters and shorelines of Duck Creek, where it occurs with other duckweeds. It is also present in waters west of the Cat Island Chain Restoration Site near Peters Marsh, the lagoon at Point au Sable, and very locally in Dead Horse Bay.
Wolffia columbiana	Common watermeal	Araceae	5	Restricted to duckweed mats of still, but generally not stagnant water, and mixed with other duckweed species. It is consistently present, but of very rare abundance, in Duck Creek and vicinity, although it is moderately common in the Point au Sable lagoon. Here, it is so plentiful in places that the water attains the consistency of a fine pea soup. It is locally present, with very rare abundance, in waters west of the Cat Island Chain Restoration Site and along shorelines of Dead Horse Bay.

Table 7b. Floating-leaf, rooted aquatic plants observed in Lower Green Bay and Fox River Area of Concern (AOC) during July and August 2017. Coefficient of conservatism values (CC value) for Wisconsin plants (WDNR Floristic Quality Assessment). Notes provide a description of distribution and abundance of each species during the sample period.

Floating-leaf, Rooted Plants				
Scientific Name	**Common Name**	**Family**	**CC Value**	**Notes**
Nuphar variegata	Bullhead pond-lily	Nymphaeaceae	6	Small populations occur in shallow waters at the north end of Dead Horse Bay and along Wequiock Creek at Point au Sable. A few individuals are present in Ashwaubenon Creek adjacent to Ashwaubomay Park.
Nymphaea odorata	Fragrant waterlily	Nymphaeaceae	6	Large colonies present only along Duck Creek and its inlets. Other occurrences consist of isolated individuals.
Persicaria amphibia	Water smartweed	Polygonaceae	5	A small population exhibiting the submerged growth form occurs along the southeastern shore of Ashwaubenon Creek adjacent to Ashwaubomay Park, north of the Fort Howard Avenue bridge. This species is more widespread in the AOC as an emergent.
Sparganium fluctuans	Floating-leaved bur-reed	Typhaceae	10	Present, but very rare, in Dead Horse Bay near the west shore of Long Tail Point.

Table 7c. Submersed aquatic plants observed in Lower Green Bay and Fox River Area of Concern (AOC) during July and August 2017. Coefficient of conservatism values (CC value) for Wisconsin plants (WDNR Floristic Quality Assessment). Notes provide a description of distribution and abundance of each species during the sample period.

Submersed Plants				
Scientific Name	**Common Name**	**Family**	**CC Value**	**Notes**
Ceratophyllum demersum	Coontail/Hornwort	Ceratophyllaceae	3	Probably the most abundant submerged aquatic species in the AOC in terms of overall biomass. It is present, often as a dominant, essentially wherever submerged aquatic vegetation can grow, and is the only species present in poor-quality sites along the lower southwest shore of the bay of Green Bay. It may, however, be absent from deeper submerged beds of the west shore dominated by *Stuckenia pectinata*.
Chara spp.	Stonewort/Muskgrass	Characeae (Charophycean green algae)	—	Present along the west side of the Cat Island Chain Restoration Site, discontinuously northward, to Dead Horse Bay. Where *Chara* is common, all submerged plants in the vicinity appear unhealthy and are covered with a thick, brownish periphyton.
Decodon verticillatus	Water-willow	Lythraceae	7	A rare species present along the southwest shore of Dead Horse Bay and also the southeastern bank of Ashwaubenon Creek north of the Fort Howard Avenue bridge. All individuals, except at the emergent marsh on the Olson/Malchow Tract, are wholly submersed and sterile. Populations consist of few, scattered individuals.
Drepanocladus sp.	Hook moss	Amblystegiaceae (pleurocarpous moss)	—	Distributed from waters west of the Cat Island Chain Restoration Site discontinuously

				northward through Dead Horse Bay; also present in the Point au Sable lagoon. Of rare abundance, except in shallow waters at the northwestern end of Dead Horse Bay, where beds of *Drepanocladus* are moderately common in some areas.
Elodea canadensis	Common waterweed	Hydrocharitaceae	3	A widely distributed species in the AOC, present in the Fox River, lower east shore, and, especially, from Duck Creek north through Dead Horse Bay. It may become common in low-quality habitat; otherwise, this species is typically present in low (rare) abundance.
Elodea nuttallii	Slender waterweed	Hydrocharitaceae	7	Restricted in distribution to Duck Creek, Wequiock Creek, and Fox River sites. Apparently absent from the bay of Green Bay. A species previously known from the AOC only by historical collections lodged at WIS. Distinguished from *E. canadensis* by its narrower leaves that typically have a 10:1 length/width ratio, and male flowers that float free from the plant at anthesis. Indeed, we observed many free-floating male flowers of *E. nuttallii* when surveying Wequiock Creek.
Heteranthera dubia	Water star-grass	Pontederiaceae	6	Most abundant in Duck Creek, where it can locally be a dominant species, and extending discontinuously northward to the southwest shore of Dead Horse Bay, in the vicinity of the Olson/Malchow Tract. The species is also present close to the mouth of the Fox River

				near the Frigo Inlet, and along Ashwaubenon Creek adjacent to Ashwaubomay Park. Of rare abundance outside of Duck Creek. Our plants are wholly submerged and, apparently, rarely flower (no flowers seen during 2016–2017 field seasons).
Myriophyllum sibiricum	Common (or Northern) water-milfoil	Haloragaceae	6	Populations of this native *Myriophyllum* species are largely restricted to a range that begins on the west shore of the Cat Island Chain Restoration Site and discontinuously extends north through Dead Horse Bay. A small and isolated population also occurs on the east shore. Throughout this range, *M. sibiricum* is of very rare to rare abundance.
Myriophyllum spicatum	Eurasian water-milfoil	Haloragaceae	0	**Invasive, introduced.** A widely distributed species in the AOC but becoming a moderately common to common dominant just in areas of Dead Horse Bay and Wequiock Creek.
Najas flexilis	Nodding water-nymph	Hydrocharitaceae	6	A rare species, with populations mostly restricted to Dead Horse Bay, where it is typically rare (but may be locally moderately common). A small population also occurs in the southern inlet of Duck Creek near Peats Lake.
Najas minor	Eutrophic water-nymph	Hydrocharitaceae	0	**Invasive, introduced.** Very local, restricted to the southwestern portion of Peats Lake, where we observed a small population near the southern inlet of Duck Creek and a second population near Ken Euers Nature Area. Fortunately, this species is currently very rare in

				the AOC. Our plants are of the fine-leaved morphotype. These occurrences represent, unfortunately, a new distributional record for Brown County.
Phragmites australis subsp. *australis*	Common reed	Poaceae	0	**Invasive, introduced.** This is the more robust and aggressive European counterpart to our native *Phragmites australis* subsp. *americanus*. Native *Phragmites* is not known to grow in the AOC area (though it does grow in an emergent marsh on the north side of Sunset Beach Road in Suamico, just outside of the northern AOC boundary). The invasive subspecies is ubiquitous in the wetter end of emergent marsh communities of the AOC, typically forming a dense, monodominant band shoreward from *Typha*. It occasionally may be found growing with the base of the plant submerged in shallow water and mixed with submerged vegetation. Such situations occur throughout AOC.
Potamogeton berchtoldii	Small pondweed	Potamogetonaceae	—	A rare species, with populations restricted to Dead Horse Bay and the shallow waters of very wet emergent marshes on Long Tail Point.
Potamogeton crispus	Curly-leaf pondweed	Potamogetonaceae	0	**Invasive, introduced.** Restricted to the Fox River and creeks that flow into Green Bay (Duck Creek, Wequiock Creek, and an unnamed creek at Olson/Malchow tract), but absent from the bay of Green Bay. Present as a moderately common dominant very locally in one slough of Wequiock Creek at Point

				au Sable; otherwise of only very rare to rare abundance.
Potamogeton epihydrus	Ribbon-leaf pondweed	Potamogetonaceae	8	A very rare and local species in the AOC, present only in Duck Creek. Plants have both floating and submersed leaves.
Potamogeton foliosus	Leafy pondweed	Potamogetonaceae	6	The most widespread *Potamogeton* species in the AOC. Leafy pondweed is present in essentially all but the most degraded and species-poor submerged marshes. It is most abundant in the Fox River system and is of mostly rare abundance elsewhere. This species has only submersed foliage.
Potamogeton nodosus	Long-leaf pondweed	Potamogetonaceae	7	Our most widespread pondweed species that produces floating leaves. It is absent from the bay of Green Bay, but consistently present in tributaries flowing into the bay, such as Wequiock Creek and Duck Creek. Also present in the Fox River. *Potamogeton nodosus* is an easily visible and distinctive species where it grows but is consistently of very rare to rare abundance.
Potamogeton pusillus	Slender pondweed	Potamogetonaceae	7	A pondweed with a limited range in the AOC, distributed in submerged marshes off the west shore of the Cat Island Chain Restoration Site, discontinuously north to the southwestern shore of Dead Horse Bay.
Potamogeton richardsonii	Richardson's pondweed	Potamogetonaceae	5	Not seen in 2017, but a few individuals found in 2016 off the E shore of the Cat Island Chain Restoration Site (east of the gate at the southern terminus of Bayshore Drive).

Potamogeton zosteriformis	Flat-stem pondweed	Potamogetonaceae	6	Not present in the bay of Green Bay, but rare to moderately common in Duck Creek and the lagoon at Point au Sable.
Stuckenia filiformis	Thread-leaved pondweed	Potamogetonaceae	8	Not known from Brown County prior to this survey, *Stuckenia filiformis* has a few, widely scattered occurrences in the AOC, present in two tributaries flowing into the bay—Wequiock Creek and Duck Creek—and is also present in submerged marshes west of the Cat Island Chain Restoration Site near Peters Marsh. It is also a very rare species in the AOC, but of the three localities at which it is present, it is easily most frequent in Wequiock Creek at Point au Sable. Our plants correspond to subsp. *occidentalis*, which is now thought to be merely a morphotype that is environmentally induced by flowing water.
Stuckenia pectinata	Sago pondweed	Potamogetonaceae	3	Likely the second-most abundant submerged species in the AOC, after *Ceratophyllum demersum* (coontail). It is present in all but the most degraded and species-poor submerged marsh communities (where only coontail can persist) and occurs in an almost continuous monodominant band in deeper water, well offshore, along the west shore of Dead Horse Bay. It is also the only species to have appreciable populations on the rocky substrates of the east shore.
Utricularia vulgaris	Common bladderwort	Lentibulariaceae	7	A species of moderate- to high-quality submerged marshes in the bay of

				Green Bay, but absent from the Fox River and major tributaries flowing into the bay (but present in Peats Lake). This species is most abundant in Dead Horse Bay and the lagoon at Point au Sable, where it is locally a dominant species. Point au Sable is the only locality where it is present outside of the west shore. The distribution of *U. vulgaris* on the west shore is from Peats Lake northward through Dead Horse Bay.
Vallisneria americana	Water celery	Hydrocharitaceae	6	An uncommon species in the AOC, with the large majority of known populations distributed in the northern half of Dead Horse Bay, where it occurs in small to medium (c. 7 m in greatest dimension) sized beds at depths of less than 1.75 m. Notable populations also exist in the Fox River. Although we documented only one medium sized bed in the Fox River, we frequently saw *Vallisneria* leaves washed up along the shoreline, suggesting more populations exist here. Small populations also exist in the northern inlet of Duck Creek, just east of the US 41/141 bridge.

Table 7d. Emergent plants in submersed form observed in Lower Green Bay and Fox River Area of Concern (AOC) during July and August 2017. Coefficient of conservatism values (CC value) for Wisconsin plants (WDNR Floristic Quality Assessment). Notes provide a description of distribution and abundance of each species during the sample period.

Emergent Plants				
Scientific Name	**Common Name**	**Family**	**CC Value**	**Notes**
Bolboschoenus fluviatilis	River bulrush	Cyperaceae	6	Healthy, reproductive populations present in Dead Horse Bay toward the shore of Long Tail Point. Rare in Duck Creek and submerged vegetation south of Peters Marsh.
Juncus effusus	Soft rush, common rush	Juncaceae	4	Locally common in shallow water in the lagoon at Point au Sable. Typically, a species of emergent marshes, where it may be frequent.
Sagittaria cuneata	Arum-leaved arrowhead	Alismataceae	7	Wholly submerged and floating-leaved growth forms of this species are widely distributed in Dead Horse Bay and Duck Creek, where they are of low (rare) abundance. Emergent growth forms are present in emergent marshes in the vicinity of Duck Creek (as observed in 2016).
Sagittaria latifolia	Broad-leaved arrowhead	Alismataceae	3	We did not observe this species to be present in any submerged marsh communities, but it is broadly distributed in the wetter zones of emergent marshes on the west shore.
Sagittaria rigida	Sessile-fruited arrowhead	Alismataceae	8	Rare. A large, heathy population is present in shallow water at the north end of Dead Horse Bay. A very small population exists in the lagoon at Point au Sable.
Schoenoplectus acutus	Hardstem bulrush	Cyperaceae	6	A rare plant in the AOC, with a few, small clonal patches present in shallow water in Dead Horse Bay and in Duck Creek.
Schoenoplectus pungens	Three-square bulrush	Cyperaceae	5	An emergent marsh species that is rarely present in shallow submerged marshes. We observed it alongside fully submerged vegetation on

				the west shore of the bay of Green Bay in Dead Horse Bay and recorded a single occurrence in Duck Creek. Such habitats are not the typical niche of this species.
Schoenoplectus tabernaemontani	Softstem bulrush	Cyperaceae	4	An emergent marsh species that is uncommonly present in shallow submerged marshes. Although we observed it alongside fully submerged vegetation on the west shore of the bay of Green Bay from Duck Creek northward through Dead Horse Bay, such habitats are not the typical niche of this species.
Sparganium eurycarpum	Common bur-reed	Typhaceae	5	We did not observe this species to be present in any submerged marsh communities, but it is broadly distributed in emergent marshes on the west shore and at Point au Sable.
Typha × *glauca*	Hybrid cattail	Typhaceae	0	**Invasive.** This hybrid between the native *Typha latifolia* and exotic *T. angustifolia* is the dominant cattail entity in the AOC. Large and robust genotypes/phenotypes of this hybrid have all but totally displaced the native *T. latifolia*. Characteristically present in the wettest ecotone of emergent marshes and delimiting a boundary with open water.
Zizania palustris	Northern wild rice	Poaceae	8	We observed several scattered, outplanted individuals of this species off the west shore of the Cat Island Chain Restoration Site.

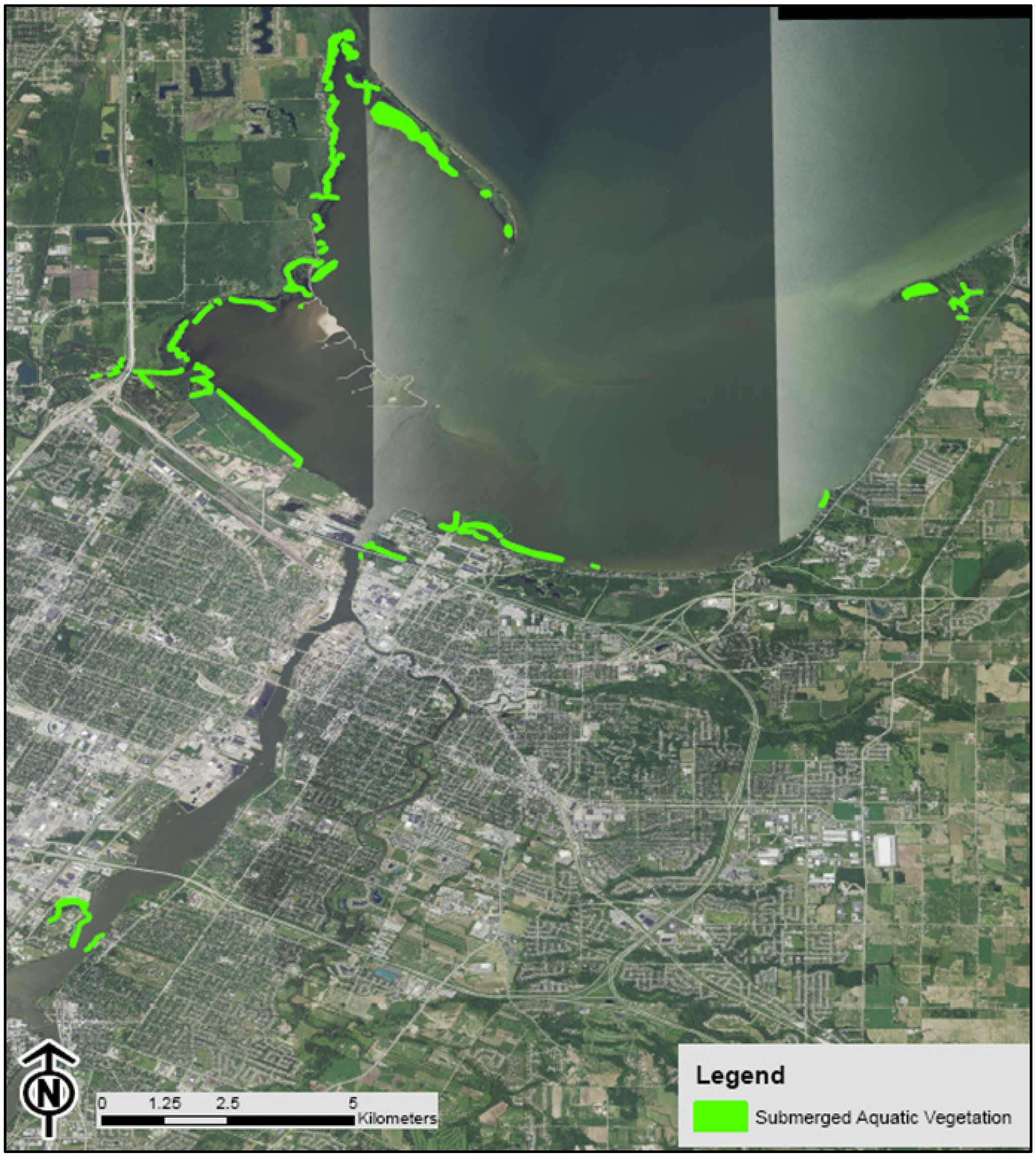


Figure 7a. Submerged Aquatic Vegetation (SAV). Green polygons represent areas within the Lower Green Bay and Fox River Area of Concern where SAV was observed during July and early August 2017.

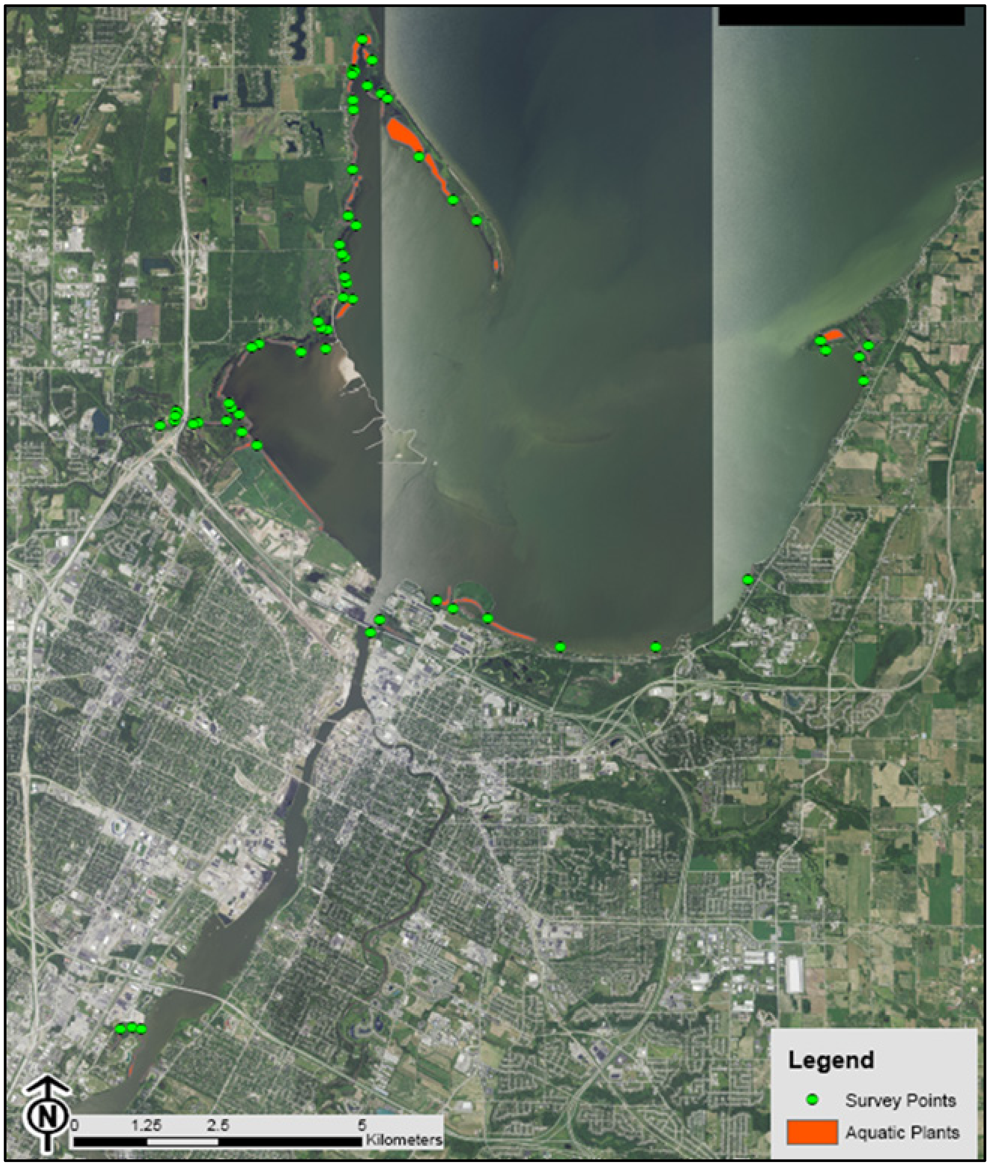


Figure 7b. Submerged Aquatic Vegetation (SAV). Orange polygons represent areas within the Lower Green Bay and Fox River Area of Concern where SAV was observed during July and early August 2017. Green circles represent sample locations.

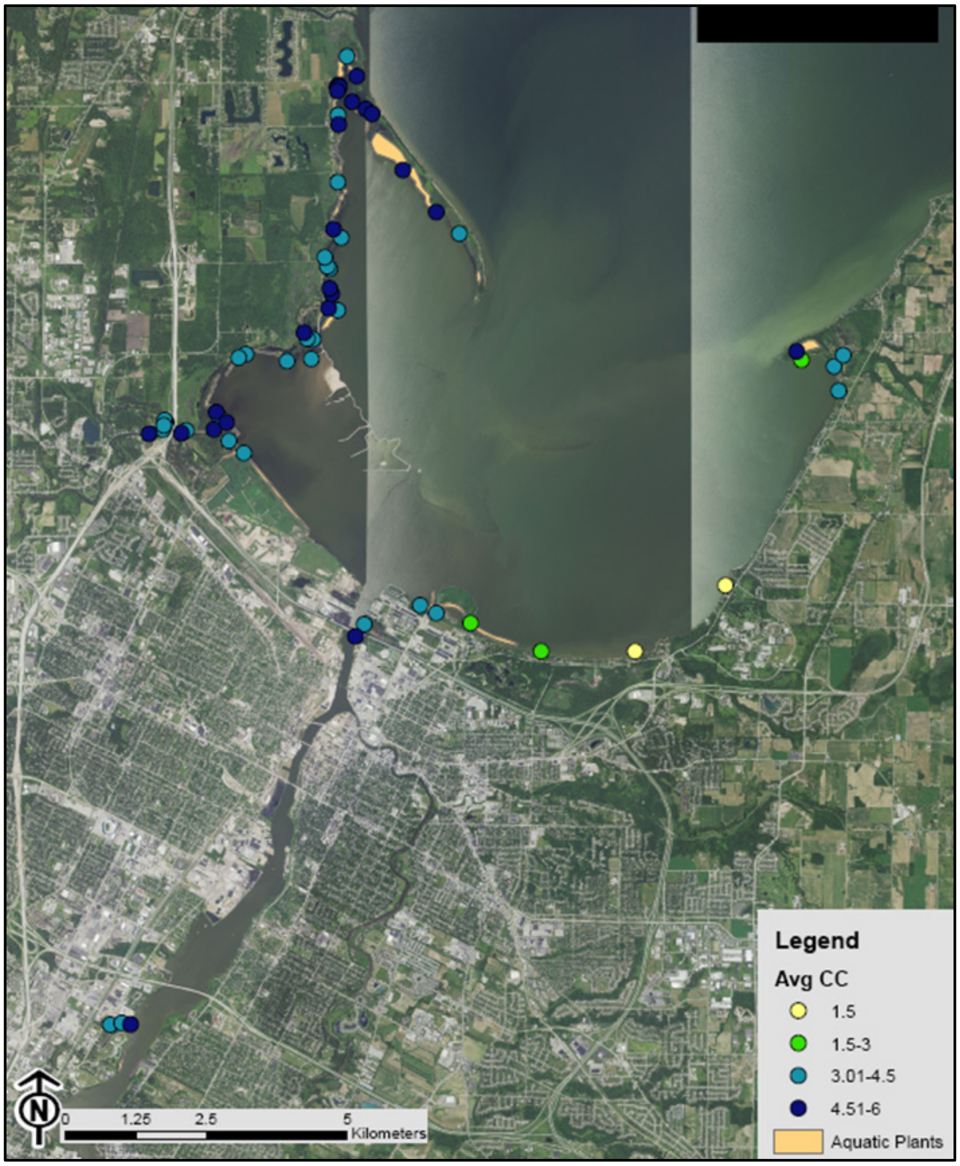


Figure 8a. Submerged Aquatic Vegetation (SAV). Average Coefficient of Conservatism at each survey point. Tan polygons represent areas within the Lower Green Bay and Fox River Area of Concern where SAV was observed during July and early August 2017.

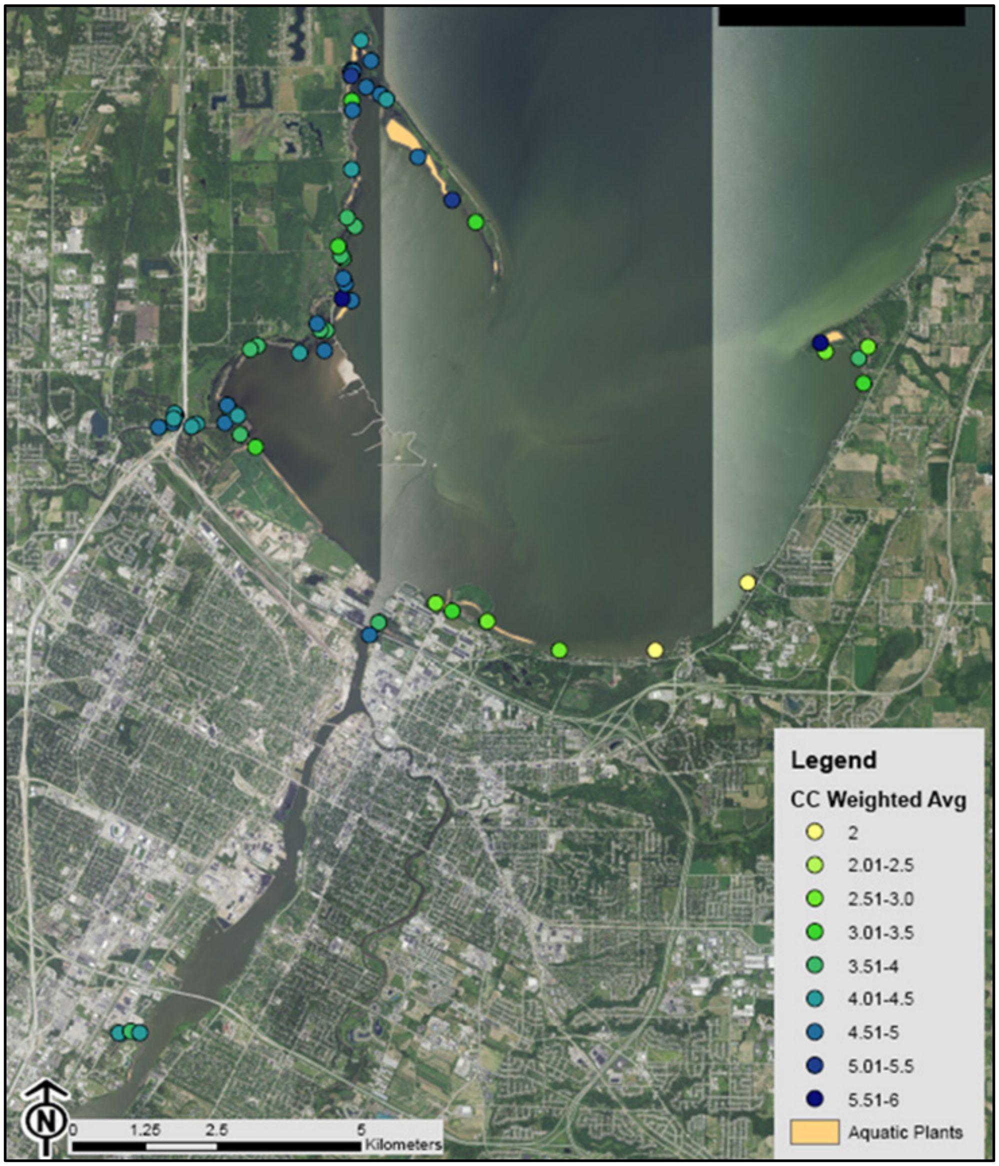


Figure 8b. Submerged Aquatic Vegetation (SAV). Weighted average Coefficient of Conservatism (CC) at each survey point. CC values were weighted by relative abundance of each species. Tan polygons represent areas within the Lower Green Bay and Fox River Area of Concern where SAV was observed during July and early August 2017.

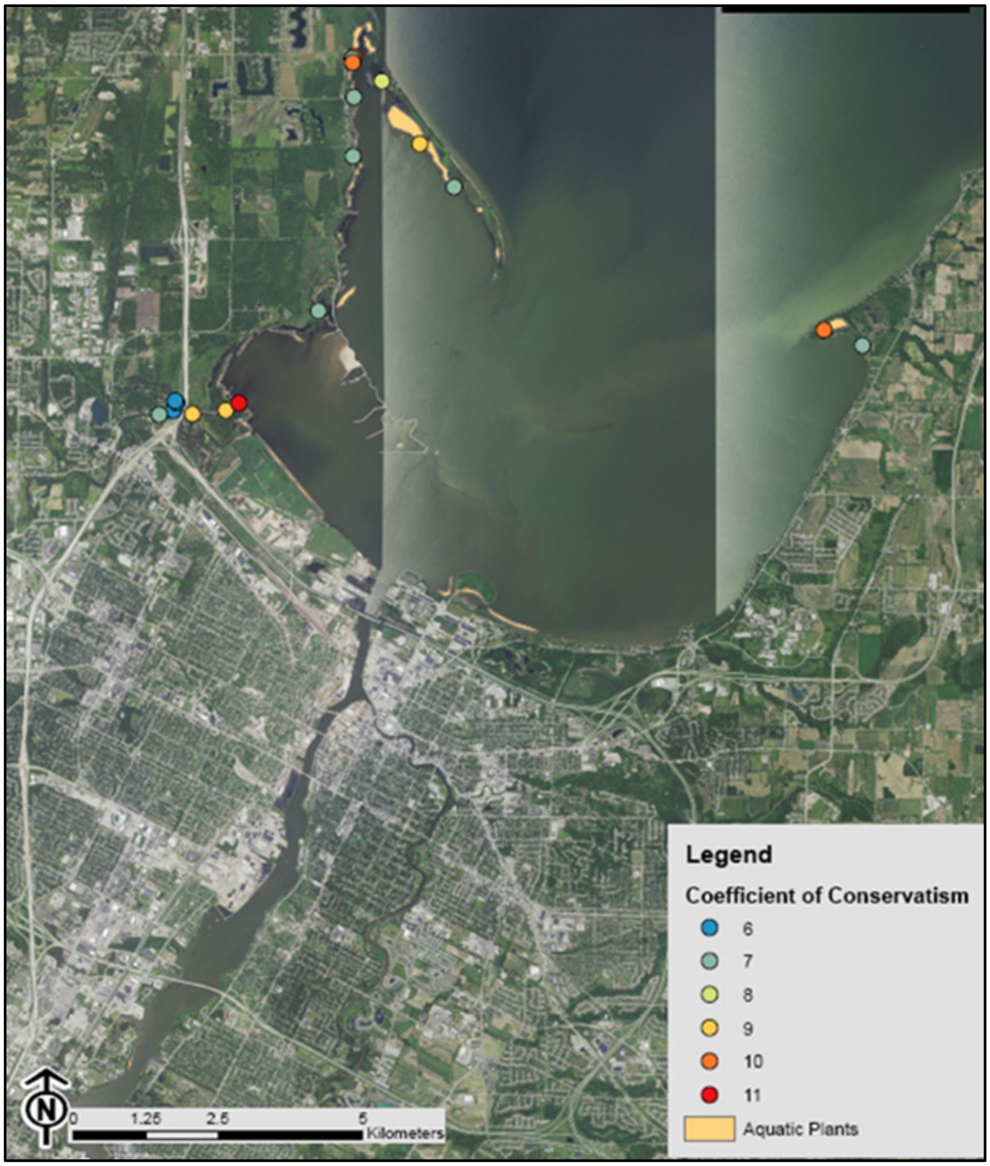


Figure 8c. Submerged Aquatic Vegetation (SAV). Areas with plant species having highest Coefficient of Conservatism. Dead Horse Bay, Duck Creek, and Point au Sable are hotspots for high quality SAV. Tan polygons represent areas within the Lower Green Bay and Fox River Area of Concern where SAV was observed during July and early August 2017.

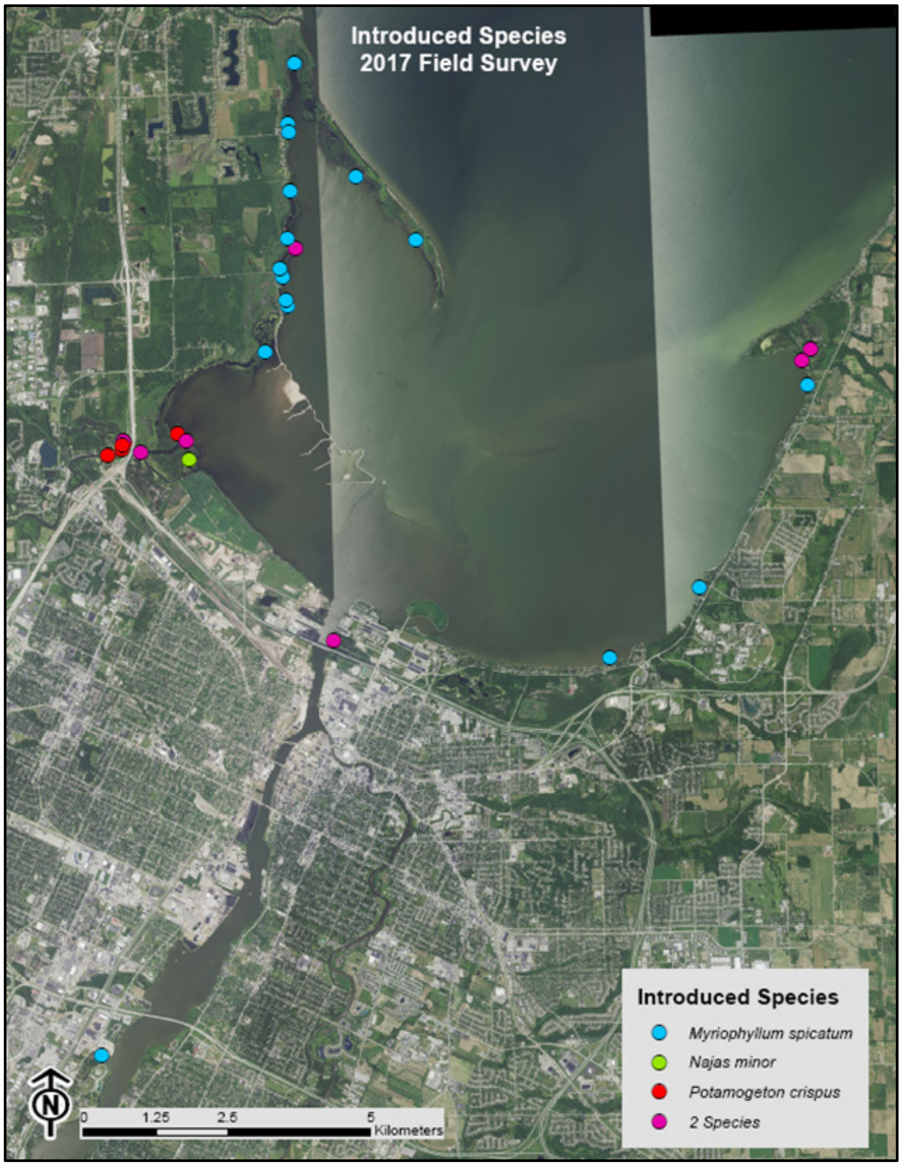


Figure 9. Submerged Aquatic Vegetation (SAV). Three species of invasive non-native plants were detected within the Lower Green Bay and Fox River Area of Concern where SAV was observed during July and early August 2017. Sites with *Myriophyllum spicatum* represented with blue circles, *Najas minor* locations with green circles, and *Potamogeton crispus* with red circles. Sites with two invasive non-native species indicated with magenta circles.

Appendix 6: EndNote Bibliography

In an effort to learn about LGB&FR AOC fish and wildlife habitats and populations, we also compiled a list of 1,271 references using EndNote. The complete list of these references is found in a 69-page file "EndNote_Bibliography_downloaded20171227.rtf" in the final data archive. We will continue to contribute to this bibliography. The latest list of references is available upon request through Erin Giese at giesee@uwgb.edu.

Appendix 7: Mapping Historical Information for the LGB&FR AOC

Appendix 7.1: Mapping Information from the Public Land Survey System

Written by Erin Giese and Ellie Roark

Introduction

In the mid-1780s, the United States federal government wanted to increase the federal budget by selling off tracts of land located in American territories west of the 13 original colonies as well as encourage settlement (Board of Commissioners of Public Lands webpage - see below). Before they could sell the land, they first needed to methodically map these lands into a grid system and carefully describe the land, which started the Public Land Survey System (PLSS; USGS website last updated in Dec 2016). In the nineteenth century, the federal government hired teams of field surveyors to delineate the western territories into a grid system though eventually the entire U.S. was mapped into this grid (USGS webpage - see below).

Field surveyors mapped the state of Wisconsin between 1833 and 1866 (Board of Commissioners of Public Lands webpage). They delineated six-mile square "townships" and one-mile square "sections." "Ranges" were vertical lines that ran north-south and separated each "township" every six miles. Aside from establishing this detailed grid system consisting of townships, ranges, and sections, they also took extremely detailed notes about the landscape and vegetation that they found at the time, which included identifying the dominant plant communities (e.g., swamp), streams, soil quality, dominant plants, etc. Although the primary purpose of these surveys was to demark boundaries, the detailed vegetation and landscape notes are invaluable to present day conservation and management efforts. However, many of the field notes were handwritten in cursive and sometimes in shorthand (i.e., shorthand format created for this specific project) on 180+ year old paper with fading ink, making it challenging to read and sometimes uninterpretable.

For more information on PLSS field methodology and how to interpret their notes, please visit:

- U.S. Geological Survey Article on the PLSS:
- https://nationalmap.gov/small_scale/a_plss.html
    - Provides general overview of PLSS and methodologies.
- Board of Commissioners of Public Land: http://digicoll.library.wisc.edu/SurveyNotes/SurveyNotesHome.html
    - Provides detailed overview of the Wisconsin PLSS including scans of original surveyors' field notes, field methodologies, and how to interpret the field notes.
- Wisconsin Department of Natural Resources' Tutorial on the PLSS Descriptions and Grid System: http://dnr.wi.gov/topic/forestmanagement/documents/plsstutorial.pdf

Digitizing Methods

Under the guidance of Robert Howe and Michael Stiefvater, UW-Green Bay graduate student, Ellie Roark, converted the township, range, and section locations described in the original, handwritten PLSS surveyor notes into geospatial coordinates along transects for all available information recorded within the boundaries of the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC) plus a 1 km buffer inland (Figure 1, Appendix 7.1). The final product of this effort was an ArcGIS shapefile containing these points. The transect points generally run north/south or east/west. However, it should be noted that these locations do not represent exact locations but rather estimated locations of where the surveyors stood. In other words, the recorded PLSS observations' proximity to the points is approximate. Only very rough, approximate measurements were done to match exact distances from the surveys to distances in the geodatabase.

Field notes were not available for all transects within the AOC, however. Where no observations are present (such as large stretches along the Fox River), no data or no relevant data were available. Many transects seemed to be incomplete when private lands overlapped a transect. Meanders along the Fox River frequently did not contain any vegetation information but only bearings for posts along the riverbank. This information was not included in the final database.

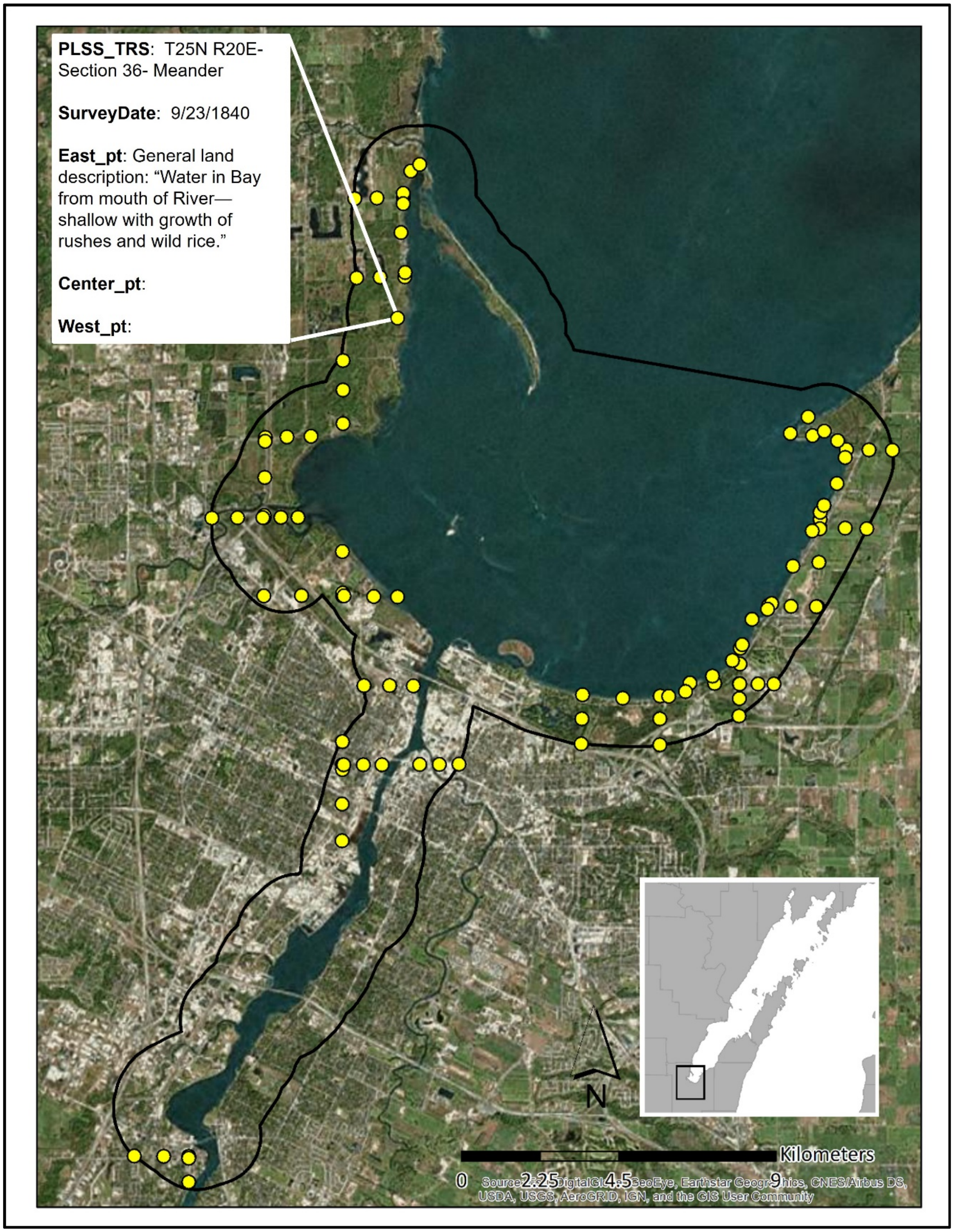
The data file name is "PLSS_SurveyData.shp".

<u>Shapefile Attribute Fields</u>:

FID - Auto-generated field by ArcGIS (e.g., 0, 1, 2, …).
Shape * - Describes the type of shape used in the shapefile, namely "multipoint."
PLSS_TRS - Public Land Survey System Township Range and Section: this field lists the township, range and section of the map to which the point corresponds.
SurveyDate - Month/day/year of survey data collection. Typically, no day was available, only month for each survey. In these cases, Roark chose "1" as the default date. Example: 9/1/1834 (month/day/year) indicates that the survey took place in the month of September. Where a specific day was noted in the survey logs, it appears in this attribute field.
East_pt - Observations near the northernmost point for latitudinal transects and ALL meanders, <u>or</u> near the easternmost point for all longitudinal transects. If a meander has the westernmost point as its northernmost point, the characteristics of that point are listed in this field, NOT in the West_pt field.
Center_pt - Observations near the central point on the transect. If no central point, no observations were listed in this field.
West_pt - Observations near the southernmost point for latitudinal transects and ALL meanders, <u>or</u> near the westernmost point for longitudinal transects.
DataSource - URL for data source from the Wisconsin historical society webpage

<u>Additional Notes on the Creation of the Shapefile/Geodatabase</u>:

- Illegible words were not noted in the creation of this database. If an entire entry was illegible, it was not entered into the database. Most entries were legible enough that even if a word was unclear, the gist of the observation was recorded. In hindsight, going through and marking which entries could be looked at by a closer eye would be helpful.
- Several things remain unclear to Roark in the vernacular of the PLSS data:
    - Tree diameters are often noted with no units. Where this was the case, Roark entered exactly what was written, which was a diameter with no units.
    - Land is characterized as 1st, 2nd or 3rd rate. Roark did not thoroughly explore what these designations mean.



PLSS_TRS: T25N R20E-Section 36- Meander

SurveyDate: 9/23/1840

East_pt: General land description: “Water in Bay from mouth of River—shallow with growth of rushes and wild rice.”

Center_pt:

West_pt:

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 1. Map of estimated locations visited by the original Wisconsin land surveyors in the 1800s converted from township, range, and section. Note that these points represent rough, approximate locations of where the surveyors stood. Map was created using ArcGIS 10.5 software and displays World Imagery and World Boundaries and Places basemaps for reference (Environmental Systems Research Institute 2016). Wisconsin inset map sources include Esri, TomTom North America, Inc., U.S. Census Bureau, U.S. Department of Agriculture, and National Agricultural Statistics Service.

Appendix 7.2: Wisconsin Land Economic Inventory Maps ("Bordner Surveys")

Introduction

Starting in 1927, the state of Wisconsin launched a statewide effort called the Wisconsin Land Economic Inventory in order to map and record all current land uses (e.g., agriculture, developed, lowland deciduous forest; Steenbock Library webpage). The primary purpose of this mapping was to be able to identify land that could potentially be resettled, forested, or used for other purposes (Steenbock Library webpage - see below). Field surveyors visited every 40-acre quarter-quarter section in the state (based on the township, range, and section grid) and recorded neighboring land cover types on paper maps, which were used in conjunction with air photographs to produce these maps that came to be known as the "Bordner Surveys" (named after the director of this project, John Bordner; Steenbock Library webpage). In addition to mapping land cover types, surveyors also noted trails, logging camps, roads, railroad lines, fire towers, town halls, and many other noteworthy features. The mapping effort ended in 1947 and thus captured how much of the state looked throughout the 1930s and 1940s (Steenbock Library webpage).

For more information on the "Bordner Surveys," please visit:

- University of Wisconsin-Madison's Steenbock Library webpage on the Bordner Surveys: https://www.library.wisc.edu/steenbock/wisconsin-land-economic-inventory-the-bordner-survey-land-cover-maps/
- Original, scanned Bordner maps: https://uwdc.library.wisc.edu/collections/econatres/wilandinv/
- Key for land use/cover types: https://maps.sco.wisc.edu/BordnerCoastal/about/#Legend

Georeferencing Methods

Under the guidance of Robert Howe and Michael Stiefvater, UW-Green Bay graduate student, Ellie Roark, georeferenced the Brown County "Bordner Survey" paper map, which was surveyed in 1945 (estimated year), and save it as a raster data file. A preview of Roark's georeferenced Bordner Survey map of the LGB&FR AOC study area is shown in Figure 2 (Appendix 7.2). The UW-Madison Dr. David Mladenoff Forest Ecosystem and Landscape Ecology Lab and the State Cartographer's Office also produced a digital, geodatabase of the statewide, Bordner Survey land use/land cover map, which is now free and available for download online: https://maps.sco.wisc.edu/BordnerCoastal/about/. You can also browse this land cover data set on their team's Coastal Bordner Project GIS portal: https://maps.sco.wisc.edu/BordnerCoastal/?featureType=polygons&basemap=streets.

The data file name is "BordnerSurvey_overlay.tif".

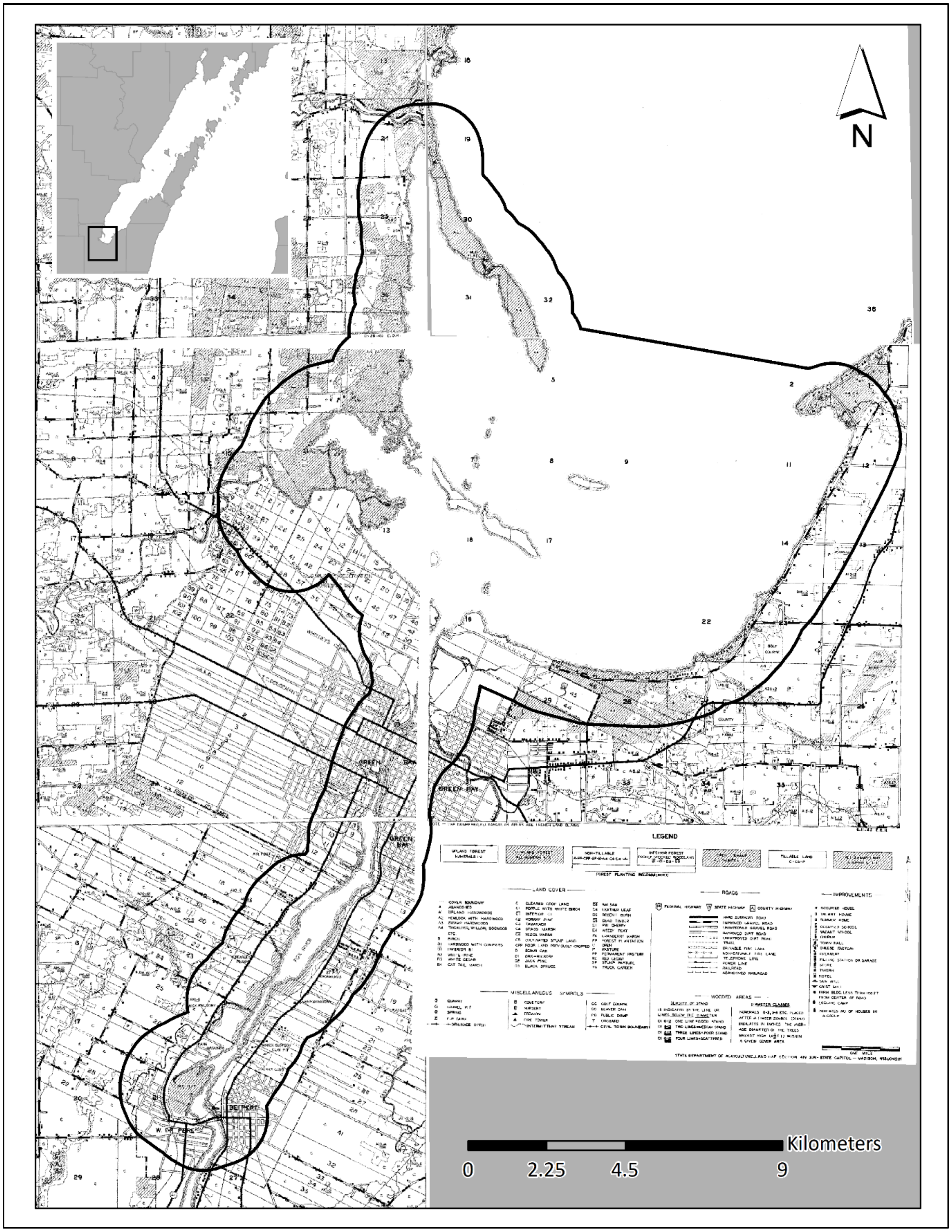


Figure 2. Georeferenced map of 1945 land uses/cover types based on the Bordner Survey of Brown County in the Lower Green Bay and Fox River Area of Concern project study area (1 km buffer shown in black outline). Paper map was georeferenced by Ellie Roark. Key for land cover types found here: https://maps.sco.wisc.edu/BordnerCoastal/about/#Legend. Map created using ArcGIS 10.5 (Environmental Systems Research Institute 2016).

Appendix 8: Table Summaries of LGB&FR AOC Biota Database

Tables 1-5 below are referenced in the “Biota Database” section in the Results text above.

Table 1. State listed species (112) that are known or expected to occur in the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC), which are stored in the LGB&FR AOC Biota Database in MS Access.

Scientific Name	Common Name	Taxon	Subtaxon	State Status
Cicindela hirticollis rhodensis	Hairy-necked Tiger Beetle	Arthropods	Insects	Endangered
Lycaeides idas	Northern Blue	Arthropods	Insects	Endangered
Speyeria idalia	Regal Fritillary	Arthropods	Insects	Endangered
Chlidonias niger	Black Tern	Birds	Other Waterbirds	Endangered
Hydroprogne caspia	Caspian Tern	Birds	Other Waterbirds	Endangered
Sterna hirundo	Common Tern	Birds	Other Waterbirds	Endangered
Sterna forsteri	Forster's Tern	Birds	Other Waterbirds	Endangered
Podiceps grisegena	Red-necked Grebe	Birds	Other Waterbirds	Endangered
Lanius ludovicianus	Loggerhead Shrike	Birds	Passerines	Endangered
Falco peregrinus	Peregrine Falcon	Birds	Raptors	Endangered
Charadrius melodus	Piping Plover	Birds	Shorebirds	Endangered
Galium palustre	Common Marsh Bedstraw	Plants	Herbs	Endangered
Thamnophis sauritus	Eastern Ribbonsnake	Reptiles	Snakes	Endangered
Regina septemvittata	Queen Snake	Reptiles	Snakes	Endangered
Lithobates catesbeianus	American Bullfrog	Amphibians	Anurans	Special Concern
Lithobates pipiens	Northern Leopard Frog	Amphibians	Anurans	Special Concern
Necturus maculosus	Common Mudpuppy	Amphibians	Salamanders	Special Concern
Bombus affinis	Rusty Patched Bumble Bee	Arthropods	Insects	Special Concern
Coccyzus erythropthalmus	Black-billed Cuckoo	Birds	Other Landbirds	Special Concern
Chordeiles minor	Common Nighthawk	Birds	Other Landbirds	Special Concern
Antrostomus vociferus	Eastern Whip-poor-will	Birds	Other Landbirds	Special Concern
Melanerpes erythrocephalus	Red-headed Woodpecker	Birds	Other Landbirds	Special Concern
Coccyzus americanus	Yellow-billed Cuckoo	Birds	Other Landbirds	Special Concern
Botaurus lentiginosus	American Bittern	Birds	Other Waterbirds	Special Concern
Pelecanus erythrorhynchos	American White Pelican	Birds	Other Waterbirds	Special Concern
Nycticorax	Black-crowned Night-Heron	Birds	Other Waterbirds	Special Concern
Bubulcus ibis	Cattle Egret	Birds	Other Waterbirds	Special Concern
Gallinula galeata	Common Gallinule	Birds	Other Waterbirds	Special Concern
Larus marinus	Great Black-backed Gull	Birds	Other Waterbirds	Special Concern
Podiceps auritus	Horned Grebe	Birds	Other Waterbirds	Special Concern
Rallus elegans	King Rail	Birds	Other Waterbirds	Special Concern
Ixobrychus exilis	Least Bittern	Birds	Other Waterbirds	Special Concern
Egretta thula	Snowy Egret	Birds	Other Waterbirds	Special Concern
Setophaga caerulescens	Black-throated Blue Warbler	Birds	Passerines	Special Concern
Vermivora cyanoptera	Blue-winged Warbler	Birds	Passerines	Special Concern
Toxostoma rufum	Brown Thrasher	Birds	Passerines	Special Concern
Cardellina canadensis	Canada Warbler	Birds	Passerines	Special Concern
Setophaga tigrina	Cape May Warbler	Birds	Passerines	Special Concern
Oporornis agilis	Connecticut Warbler	Birds	Passerines	Special Concern
Spiza americana	Dickcissel	Birds	Passerines	Special Concern
Sturnella magna	Eastern Meadowlark	Birds	Passerines	Special Concern

Spizella pusilla	Field Sparrow	Birds	Passerines	Special Concern
Vermivora chrysoptera	Golden-winged Warbler	Birds	Passerines	Special Concern
Ammodramus savannarum	Grasshopper Sparrow	Birds	Passerines	Special Concern
Chondestes grammacus	Lark Sparrow	Birds	Passerines	Special Concern
Ammodramus leconteii	Le Conte's Sparrow	Birds	Passerines	Special Concern
Empidonax minimus	Least Flycatcher	Birds	Passerines	Special Concern
Vireo philadelphicus	Philadelphia Vireo	Birds	Passerines	Special Concern
Protonotaria citrea	Prothonotary Warbler	Birds	Passerines	Special Concern
Progne subis	Purple Martin	Birds	Passerines	Special Concern
Loxia curvirostra	Red Crossbill	Birds	Passerines	Special Concern
Regulus calendula	Ruby-crowned Kinglet	Birds	Passerines	Special Concern
Euphagus carolinus	Rusty Blackbird	Birds	Passerines	Special Concern
Catharus ustulatus	Swainson's Thrush	Birds	Passerines	Special Concern
Pooecetes gramineus	Vesper Sparrow	Birds	Passerines	Special Concern
Sturnella neglecta	Western Meadowlark	Birds	Passerines	Special Concern
Loxia leucoptera	White-winged Crossbill	Birds	Passerines	Special Concern
Empidonax traillii	Willow Flycatcher	Birds	Passerines	Special Concern
Cardellina pusilla	Wilson's Warbler	Birds	Passerines	Special Concern
Hylocichla mustelina	Wood Thrush	Birds	Passerines	Special Concern
Xanthocephalus	Yellow-headed Blackbird	Birds	Passerines	Special Concern
Haliaeetus leucocephalus	Bald Eagle	Birds	Raptors	Special Concern
Circus cyaneus	Northern Harrier	Birds	Raptors	Special Concern
Asio flammeus	Short-eared Owl	Birds	Raptors	Special Concern
Pluvialis dominica	American Golden-Plover	Birds	Shorebirds	Special Concern
Scolopax minor	American Woodcock	Birds	Shorebirds	Special Concern
Himantopus mexicanus	Black-necked Stilt	Birds	Shorebirds	Special Concern
Tryngites subruficollis	Buff-breasted Sandpiper	Birds	Shorebirds	Special Concern
Calidris alpina	Dunlin	Birds	Shorebirds	Special Concern
Limosa haemastica	Hudsonian Godwit	Birds	Shorebirds	Special Concern
Limnodromus griseus	Short-billed Dowitcher	Birds	Shorebirds	Special Concern
Tringa solitaria	Solitary Sandpiper	Birds	Shorebirds	Special Concern
Numenius phaeopus	Whimbrel	Birds	Shorebirds	Special Concern
Phalaropus tricolor	Wilson's Phalarope	Birds	Shorebirds	Special Concern
Anas rubripes	American Black Duck	Birds	Waterfowl	Special Concern
Anas discors	Blue-winged Teal	Birds	Waterfowl	Special Concern
Aythya valisineria	Canvasback	Birds	Waterfowl	Special Concern
Bucephala clangula	Common Goldeneye	Birds	Waterfowl	Special Concern
Aythya affinis	Lesser Scaup	Birds	Waterfowl	Special Concern
Anas acuta	Northern Pintail	Birds	Waterfowl	Special Concern
Aythya americana	Redhead	Birds	Waterfowl	Special Concern
Oxyura jamaicensis	Ruddy Duck	Birds	Waterfowl	Special Concern
Anguilla rostrata	American Eel	Fish		Special Concern
Fundulus diaphanus	Banded Killifish	Fish		Special Concern
Acipenser fulvescens	Lake Sturgeon	Fish		Special Concern
Lasionycteris noctivagans	Silver-Haired Bat	Mammals	Bats	Special Concern
Sorex palustris	American Water Shrew	Mammals	Rodents	Special Concern
Glaucomys sabrinus	Northern Flying Squirrel	Mammals	Rodents	Special Concern
Microtus ochrogaster	Prairie Vole	Mammals	Rodents	Special Concern

Napaeozapus insignis	Woodland Jumping Mouse	Mammals	Rodents	Special Concern
Microtus pinetorum	Woodland Vole	Mammals	Rodents	Special Concern
Cakile edentula var. lacustris	American Sea-rocket	Plants	Herbs	Special Concern
Juglans cinerea	Butternut	Plants	Trees	Special Concern
Thamnophis butleri	Butler's Garter Snake	Reptiles	Snakes	Special Concern
Emydoidea blandingii	Blanding's Turtle	Reptiles	Turtles	Special Concern
Ardea alba	Great Egret	Birds	Other Waterbirds	Threatened
Nyctanassa violacea	Yellow-crowned Night Heron	Birds	Other Waterbirds	Threatened
Empidonax virescens	Acadian Flycatcher	Birds	Passerines	Threatened
Setophaga cerulea	Cerulean Warbler	Birds	Passerines	Threatened
Ammodramus henslowii	Henslow's Sparrow	Birds	Passerines	Threatened
Setophaga citrina	Hooded Warbler	Birds	Passerines	Threatened
Geothlypis formosa	Kentucky Warbler	Birds	Passerines	Threatened
Buteo lineatus	Red-shouldered Hawk	Birds	Raptors	Threatened
Bartramia longicauda	Upland Sandpiper	Birds	Shorebirds	Threatened
Lepomis megalotis	Longear Sunfish	Fish		Threatened
Moxostoma carinatum	River Redhorse	Fish		Threatened
Eptesicus fuscus	Big Brown Bat	Mammals	Bats	Threatened
Myotis lucifugus	Little Brown Bat	Mammals	Bats	Threatened
Myotis septentrionalis	Northern Long-Eared Bat	Mammals	Bats	Threatened
Perimyotis subflavus	Tricolored Bat	Mammals	Bats	Threatened
Trillium nivale	Snow Trillium	Plants	Herbs	Threatened
Glyptemys insculpta	Wood Turtle	Reptiles	Turtles	Threatened

Table 2. State ranked species (107) that are known or expected to occur in the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC), which are stored in the LGB&FR AOC Biota Database in MS Access.

Scientific Name	Common Name	Taxon	Subtaxon	State Rank
Cicindela hirticollis rhodensis	Hairy-necked Tiger Beetle	Arthropods	Insects	S1
Lycaeides idas	Northern Blue	Arthropods	Insects	S1
Speyeria idalia	Regal Fritillary	Arthropods	Insects	S1
Bombus affinis	Rusty Patched Bumble Bee	Arthropods	Insects	S1
Hydroprogne caspia	Caspian Tern	Birds	Other Waterbirds	S1
Sterna hirundo	Common Tern	Birds	Other Waterbirds	S1
Sterna forsteri	Forster's Tern	Birds	Other Waterbirds	S1
Rallus elegans	King Rail	Birds	Other Waterbirds	S1
Podiceps grisegena	Red-necked Grebe	Birds	Other Waterbirds	S1
Nyctanassa violacea	Yellow-crowned Night Heron	Birds	Other Waterbirds	S1
Geothlypis formosa	Kentucky Warbler	Birds	Passerines	S1
Lanius ludovicianus	Loggerhead Shrike	Birds	Passerines	S1
Falco peregrinus	Peregrine Falcon	Birds	Raptors	S1
Asio flammeus	Short-eared Owl	Birds	Raptors	S1
Charadrius melodus	Piping Plover	Birds	Shorebirds	S1
Phalaropus tricolor	Wilson's Phalarope	Birds	Shorebirds	S1
Myotis septentrionalis	Northern Long-Eared Bat	Mammals	Bats	S1
Perimyotis subflavus	Tricolored Bat	Mammals	Bats	S1
Galium palustre	Common Marsh Bedstraw	Plants	Herbs	S1
Thamnophis sauritus	Eastern Ribbonsnake	Reptiles	Snakes	S1
Regina septemvittata	Queen Snake	Reptiles	Snakes	S1
Sparbarus lacustris	A Small Square-gilled Mayfly	Arthropods	Insects	S2
Hesperia metea	Cobweb Skipper	Arthropods	Insects	S2
Erynnis lucilius	Columbine Duskywing	Arthropods	Insects	S2
Libellula incesta	Slaty Skimmer	Arthropods	Insects	S2
Chordeiles minor	Common Nighthawk	Birds	Other Landbirds	S2
Chlidonias niger	Black Tern	Birds	Other Waterbirds	S2
Nycticorax	Black-crowned Night-Heron	Birds	Other Waterbirds	S2
Ardea alba	Great Egret	Birds	Other Waterbirds	S2
Ixobrychus exilis	Least Bittern	Birds	Other Waterbirds	S2
Setophaga cerulea	Cerulean Warbler	Birds	Passerines	S2
Oporornis agilis	Connecticut Warbler	Birds	Passerines	S2
Sturnella magna	Eastern Meadowlark	Birds	Passerines	S2
Ammodramus henslowii	Henslow's Sparrow	Birds	Passerines	S2
Setophaga citrina	Hooded Warbler	Birds	Passerines	S2
Ammodramus leconteii	Le Conte's Sparrow	Birds	Passerines	S2
Progne subis	Purple Martin	Birds	Passerines	S2
Regulus calendula	Ruby-crowned Kinglet	Birds	Passerines	S2
Catharus ustulatus	Swainson's Thrush	Birds	Passerines	S2
Pooecetes gramineus	Vesper Sparrow	Birds	Passerines	S2

Sturnella neglecta	Western Meadowlark	Birds	Passerines	S2
Scolopax minor	American Woodcock	Birds	Shorebirds	S2
Bartramia longicauda	Upland Sandpiper	Birds	Shorebirds	S2
Anas rubripes	American Black Duck	Birds	Waterfowl	S2
Aythya valisineria	Canvasback	Birds	Waterfowl	S2
Bucephala clangula	Common Goldeneye	Birds	Waterfowl	S2
Aythya americana	Redhead	Birds	Waterfowl	S2
Lepomis megalotis	Longear Sunfish	Fish		S2
Moxostoma carinatum	River Redhorse	Fish		S2
Myotis lucifugus	Little Brown Bat	Mammals	Bats	S2
Microtus ochrogaster	Prairie Vole	Mammals	Rodents	S2
Napaeozapus insignis	Woodland Jumping Mouse	Mammals	Rodents	S2
Microtus pinetorum	Woodland Vole	Mammals	Rodents	S2
Juglans cinerea	Butternut	Plants	Trees	S2
Lithobates catesbeianus	American Bullfrog	Amphibians	Anurans	S3
Necturus maculosus	Common Mudpuppy	Amphibians	Salamanders	S3
Cordulegaster obliqua	Arrowhead Spiketail	Arthropods	Insects	S3
Euphydryas phaeton	Baltimore Checkerspot	Arthropods	Insects	S3
Aeshna tuberculifera	Black-tipped Darner	Arthropods	Insects	S3
Chlosyne gorgone	Gorgone Checkerspot	Arthropods	Insects	S3
Aeshna verticalis	Green-striped Darner	Arthropods	Insects	S3
Arigomphus cornutus	Horned Clubtail	Arthropods	Insects	S3
Arigomphus furcifer	Lilypad Clubtail	Arthropods	Insects	S3
Pompeius verna	Little Glassywing	Arthropods	Insects	S3
Tramea onusta	Red Saddlebags	Arthropods	Insects	S3
Stylurus plagiatus	Russet-tipped Clubtail	Arthropods	Insects	S3
Lestes vigilax	Swamp Spreadwing	Arthropods	Insects	S3
Phyciodes batesii	Tawny Crescent	Arthropods	Insects	S3
Antrostomus vociferus	Eastern Whip-poor-will	Birds	Other Landbirds	S3
Melanerpes erythrocephalus	Red-headed Woodpecker	Birds	Other Landbirds	S3
Coccyzus americanus	Yellow-billed Cuckoo	Birds	Other Landbirds	S3
Botaurus lentiginosus	American Bittern	Birds	Other Waterbirds	S3
Pelecanus erythrorhynchos	American White Pelican	Birds	Other Waterbirds	S3
Gallinula galeata	Common Gallinule	Birds	Other Waterbirds	S3
Empidonax virescens	Acadian Flycatcher	Birds	Passerines	S3
Setophaga caerulescens	Black-throated Blue Warbler	Birds	Passerines	S3
Cardellina canadensis	Canada Warbler	Birds	Passerines	S3
Setophaga tigrina	Cape May Warbler	Birds	Passerines	S3
Spiza americana	Dickcissel	Birds	Passerines	S3
Spizella pusilla	Field Sparrow	Birds	Passerines	S3
Vermivora chrysoptera	Golden-winged Warbler	Birds	Passerines	S3
Ammodramus savannarum	Grasshopper Sparrow	Birds	Passerines	S3
Chondestes grammacus	Lark Sparrow	Birds	Passerines	S3

Protonotaria citrea	Prothonotary Warbler	Birds	Passerines	S3
Xanthocephalus	Yellow-headed Blackbird	Birds	Passerines	S3
Circus cyaneus	Northern Harrier	Birds	Raptors	S3
Buteo lineatus	Red-shouldered Hawk	Birds	Raptors	S3
Pluvialis dominica	American Golden-Plover	Birds	Shorebirds	S3
Tryngites subruficollis	Buff-breasted Sandpiper	Birds	Shorebirds	S3
Aythya affinis	Lesser Scaup	Birds	Waterfowl	S3
Anguilla rostrata	American Eel	Fish		S3
Fundulus diaphanus	Banded Killifish	Fish		S3
Acipenser fulvescens	Lake Sturgeon	Fish		S3
Lasiurus cinereus	Hoary Bat	Mammals	Bats	S3
Lasionycteris noctivagans	Silver-Haired Bat	Mammals	Bats	S3
Sorex palustris	American Water Shrew	Mammals	Rodents	S3
Glaucomys sabrinus	Northern Flying Squirrel	Mammals	Rodents	S3
Toxolasma parvus	Lilliput	Mollusks	Mussels	S3
Cakile edentula var. lacustris	American Sea-rocket	Plants	Herbs	S3
Trillium nivale	Snow Trillium	Plants	Herbs	S3
Thamnophis butleri	Butler's Garter Snake	Reptiles	Snakes	S3
Emydoidea blandingii	Blanding's Turtle	Reptiles	Turtles	S3
Glyptemys insculpta	Wood Turtle	Reptiles	Turtles	S3
Vireo philadelphicus	Philadelphia Vireo	Birds	Passerines	SU
Loxia curvirostra	Red Crossbill	Birds	Passerines	SU
Loxia leucoptera	White-winged Crossbill	Birds	Passerines	SU
Cardellina pusilla	Wilson's Warbler	Birds	Passerines	SU

Table 3. Globally listed species (12) that are known or expected to occur in the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC), which are stored in the LGB&FR AOC Biota Database in MS Access.

Scientific Name	Common Name	Taxon	Subtaxon	Global Status
Bombus affinis	Rusty Patched Bumble Bee	Arthropods	Insects	G1
Myotis septentrionalis	Northern Long-Eared Bat	Mammals	Bats	G1
Speyeria idalia	Regal Fritillary	Arthropods	Insects	G3
Charadrius melodus	Piping Plover	Birds	Shorebirds	G3
Acipenser fulvescens	Lake Sturgeon	Fish		G3
Clinostomus elongatus	Redside Dace	Fish		G3
Lasiurus borealis	Eastern Red Bat	Mammals	Bats	G3
Myotis lucifugus	Little Brown Bat	Mammals	Bats	G3
Lasionycteris noctivagans	Silver-Haired Bat	Mammals	Bats	G3
Perimyotis subflavus	Tricolored Bat	Mammals	Bats	G3
Toxolasma parvus	Lilliput	Mollusks	Mussels	G3
Glyptemys insculpta	Wood Turtle	Reptiles	Turtles	G3

Table 4. Species (22) listed using the International Union for Conservation of Nature and Natural Resources (IUCN) ratings that are known or expected to occur in the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC), which are stored in the LGB&FR AOC Biota Database in MS Access.

Scientific Name	Common Name	Taxon	Subtaxon	IUCN Status
Bombus affinis	Rusty Patched Bumble Bee	Arthropods	Insects	CR
Anguilla rostrata	American Eel	Fish		EN
Emydoidea blandingii	Blanding's Turtle	Reptiles	Turtles	EN
Glyptemys insculpta	Wood Turtle	Reptiles	Turtles	EN
Chaetura pelagica	Chimney Swift	Birds	Other Landbirds	NT
Melanerpes erythrocephalus	Red-headed Woodpecker	Birds	Other Landbirds	NT
Rallus elegans	King Rail	Birds	Other Waterbirds	NT
Vermivora chrysoptera	Golden-winged Warbler	Birds	Passerines	NT
Ammodramus henslowii	Henslow's Sparrow	Birds	Passerines	NT
Contopus cooperi	Olive-sided Flycatcher	Birds	Passerines	NT
Tryngites subruficollis	Buff-breasted Sandpiper	Birds	Shorebirds	NT
Calidris pusilla	Semipalmated Sandpiper	Birds	Shorebirds	NT
Melanitta americana	Black Scoter	Birds	Waterfowl	NT
Somateria mollissima	Common Eider	Birds	Waterfowl	NT
Sonchus arvensis	Field Sowthistle	Plants	Herbs	NT
Tsuga canadensis	Eastern Hemlock	Plants	Trees	NT
Rissa tridactyla	Black-legged Kittiwake	Birds	Other Waterbirds	VU
Setophaga cerulea	Cerulean Warbler	Birds	Passerines	VU
Euphagus carolinus	Rusty Blackbird	Birds	Passerines	VU
Charadrius melodus	Piping Plover	Birds	Shorebirds	VU
Clangula hyemalis	Long-tailed Duck	Birds	Waterfowl	VU
Coregonus hoyi	Bloater	Fish		VU

Table 5. List bird species (102) that are known or expected to occur in the Lower Green Bay and Fox River Area of Concern (LGB&FR AOC), which are stored in the LGB&FR AOC Biota Database in MS Access. SGCN = Wisconsin Wildlife Action Plan Species of Greatest Concern watch list, PIF = Partners in Flight priorities from Bird Conservation Regions 12 and 23 and Continental Watch List species, SBIRD = Regional/continental priorities from the Upper Miss/Great Lakes Joint Venture Shorebird Plan, WBIRD = Upper Mississippi River/Great Lakes Waterbird Conservation Plan, and WFOWL = Regional priorities from the North American Waterfowl Management Plan.

Scientific Name	Common Name	SGCN	PIF	SBIRD	WBIRD	WFOWL
Empidonax virescens	Acadian Flycatcher	x	x			
Botaurus lentiginosus	American Bittern	x			x	
Anas rubripes	American Black Duck	x				x
Pluvialis dominica	American Golden-Plover	x		x		
Scolopax minor	American Woodcock	x		x		
Haliaeetus leucocephalus	Bald Eagle	x				
Riparia	Bank Swallow		x			
Hirundo rustica	Barn Swallow		x			
Megaceryle alcyon	Belted Kingfisher		x			
Chlidonias niger	Black Tern	x			x	
Coccyzus erythropthalmus	Black-billed Cuckoo	x	x			
Setophaga fusca	Blackburnian Warbler		x			
Setophaga caerulescens	Black-throated Blue Warbler	x	x			
Setophaga virens	Black-throated Green Warbler		x			
Anas discors	Blue-winged Teal	x				
Vermivora cyanoptera	Blue-winged Warbler	x	x			
Dolichonyx oryzivorus	Bobolink	x	x			
Buteo platypterus	Broad-winged Hawk		x			
Toxostoma rufum	Brown Thrasher	x	x			
Tryngites subruficollis	Buff-breasted Sandpiper	x		x		
Branta canadensis	Canada Goose					x
Cardellina canadensis	Canada Warbler	x	x			
Aythya valisineria	Canvasback	x				
Hydroprogne caspia	Caspian Tern	x				
Setophaga cerulea	Cerulean Warbler	x	x			
Setophaga pensylvanica	Chestnut-sided Warbler		x			
Chaetura pelagica	Chimney Swift		x			
Spizella pallida	Clay-colored Sparrow		x			
Sterna hirundo	Common Tern	x			x	
Geothlypis trichas	Common Yellowthroat		x			
Oporornis agilis	Connecticut Warbler	x	x			
Spiza americana	Dickcissel	x	x			
Calidris alpina	Dunlin	x		x		
Sturnella magna	Eastern Meadowlark	x	x			
Antrostomus vociferus	Eastern Whip-poor-will	x	x			
Spizella pusilla	Field Sparrow	x	x			
Sterna forsteri	Forster's Tern	x				
Vermivora chrysoptera	Golden-winged Warbler	x	x			
Ammodramus savannarum	Grasshopper Sparrow	x	x			

Ardea alba	Great Egret	x				
Tringa melanoleuca	Greater Yellowlegs			x		
Ammodramus henslowii	Henslow's Sparrow	x				
Lophodytes cucullatus	Hooded Merganser					x
Setophaga citrina	Hooded Warbler	x				
Podiceps auritus	Horned Grebe	x				
Limosa haemastica	Hudsonian Godwit	x		x		
Geothlypis formosa	Kentucky Warbler	x				
Rallus elegans	King Rail	x			x	
Chondestes grammacus	Lark Sparrow	x				
Ammodramus leconteii	Le Conte's Sparrow	x				
Ixobrychus exilis	Least Bittern				x	
Empidonax minimus	Least Flycatcher	x	x			
Aythya affinis	Lesser Scaup	x				x
Lanius ludovicianus	Loggerhead Shrike	x				
Anas platyrhynchos	Mallard					x
Limosa fedoa	Marbled Godwit	x		x		
Cistothorus palustris	Marsh Wren		x			
Geothlypis philadelphia	Mourning Warbler		x			
Oreothlypis ruficapilla	Nashville Warbler		x			
Colaptes auratus	Northern Flicker		x			
Circus cyaneus	Northern Harrier	x	x			
Anas acuta	Northern Pintail					x
Stelgidopteryx serripennis	Northern Rough-winged Swallow		x			
Contopus cooperi	Olive-sided Flycatcher	x	x			
Pandion haliaetus	Osprey	x				
Falco peregrinus	Peregrine Falcon	x				
Podilymbus podiceps	Pied-billed Grebe				x	
Charadrius melodus	Piping Plover	x		x		
Protonotaria citrea	Prothonotary Warbler	x				
Haemorhous purpureus	Purple Finch		x			
Loxia curvirostra	Red Crossbill	x				
Aythya americana	Redhead	x				
Melanerpes erythrocephalus	Red-headed Woodpecker	x	x			
Podiceps grisegena	Red-necked Grebe	x			x	
Buteo lineatus	Red-shouldered Hawk	x				
Pheucticus ludovicianus	Rose-breasted Grosbeak		x			
Bonasa umbellus	Ruffed Grouse		x			
Euphagus carolinus	Rusty Blackbird	x	x			
Cistothorus platensis	Sedge Wren		x			
Limnodromus griseus	Short-billed Dowitcher	x		x		
Asio flammeus	Short-eared Owl	x	x			
Egretta thula	Snowy Egret	x				
Tringa solitaria	Solitary Sandpiper	x		x		
Porzana carolina	Sora				x	

Melospiza georgiana	Swamp Sparrow		x		
Cygnus buccinator	Trumpeter Swan	x			
Cygnus columbianus	Tundra Swan				x
Bartramia longicauda	Upland Sandpiper	x		x	
Catharus fuscescens	Veery	x	x		
Pooecetes gramineus	Vesper Sparrow		x		
Vireo gilvus	Warbling Vireo		x		
Sturnella neglecta	Western Meadowlark	x	x		
Numenius phaeopus	Whimbrel	x		x	
Zonotrichia albicollis	White-throated Sparrow		x		
Empidonax traillii	Willow Flycatcher	x	x		
Phalaropus tricolor	Wilson's Phalarope	x		x	
Hylocichla mustelina	Wood Thrush	x	x		
Sphyrapicus varius	Yellow-bellied Sapsucker		x		
Coccyzus americanus	Yellow-billed Cuckoo	x			
Nyctanassa violacea	Yellow-crowned Night Heron	x			
Xanthocephalus	Yellow-headed Blackbird		x		
Vireo flavifrons	Yellow-throated Vireo		x		

Appendix 9: Project Recommendations

Table 1. List of recommended objectives and projects for the LGB&FR AOC and their associated impacted priority habitats and populations. Version 20 December 2017.

Objectives	Projects	Impacted Habitats + Populations (ordered alphabetically first and then by habitat)
1. Manage and protect AOC islands.	1. Develop and implement Cat Island Habitat and Wildlife Management Plan that addresses invasive plant species control, strategic placement of dredge material, public access restrictions, predator control, shoreline management, etc. 2. Construct and maintain island structures for nesting colonial waterbirds, especially endangered terns. 3. Protect and monitor Piping Plover (*Charadrius melodus*) breeding populations at Cat Island Chain Restoration Site and at least one other location. 4. Identify and protect safe roosting areas for wintering Bald Eagles (*Haliaeetus leucocephalus*) and other seasonal bird populations (e.g., Snowy Owls, *Bubo scandiacus*). 5. Create and manage intermittently flooded shoreline habitat for shorebirds on Green Bay islands and shoals. 6. Locate and protect heron rookeries; inform land managers and provide guidance for protection measures. 7. Place woody debris for fish habitat.	1. EMHE, GLBE, SAVG, ANURAN, COLWAT, CWMUST, MBBIRD, CTM, PIPL, SHFISH, TURTLE, and WATERF 2. COLWAT 3. PIPL 4. BAEA 5. CTM and SHOREB 6. COLWAT 7. SHFISH
2. Expand and improve Great Lakes beach habitat.	8. Control woody successional and invasive plant species, remove accumulated zebra/quagga mussel shells, and restore native vegetation at undeveloped east shore beaches (Point au Sable, UW-Green Bay campus, Joliet Park, Bay Beach region). 9. Conduct biotic inventories along AOC shoreline and if necessary re-establish populations of native turtle species and other beach specialists. 10. Identify critical buffer habitats and shorelines with potential den sites for mink, otter, and other shoreline wildlife species. 11. Improve natural beach habitat at Longtail Point; identify sensitive areas where human access can be restricted during breeding season of priority species.	8. GLBE, CWMUST, CTM, SHOREB, and TURTLE 9. GLBE, CWMUST, CTM, PIPL, SHOREB, and TURTLE 10. GLBE, CWMUST, CTM, PIPL, SHOREB, and TURTLE 11. SHOREB, TURTLE, CTM, CWMUST
3. Restore and enhance southern sedge meadow habitat.	12. Expand existing southern sedge meadow remnants at the Malchow-Olson Tract, Point au Sable, Fort Howard Wildlife Area, Duck Creek, and small areas upstream along the East River. Control invasive plant species, restore hydrology, and promote the spread of	12. SSME, ANURAN, BATS, CWAQMA, CWMUST, LANDBI, MBBIRD, and WETTER 13. SSME, ANURAN, CWAQMA,

	native plant species (especially tussock forming sedge, *Carex stricta*). 13. Restore extensive southern sedge meadow/wet meadow habitat in northern Duck Creek delta (Wisconsin DNR lands east of E. Greenfield Ave).	CWMUST, LANDBI, MBBIRD, and WETTER
4. Improve habitat quality of small AOC tributaries (enhance fish passage, restore natural stream substrates, and protect riparian vegetation)	14. Use The Nature Conservancy's fish passage GIS tool to identify and remove barriers that provide access to potential spawning areas. 15. Improve substrate (including gravel, riffles, and pool habitat) and reduce sediment pollution. 16. Protect and enhance riparian habitats at Mahon Creek, Wequiock Creek, Duck Creek, and parts of the East River. 17. Reduce magnitude of storm surges (flashiness) by creating or maintaining upstream vegetation buffers and mitigating inputs from stormwater drainages. 18. Stabilize falling banks to reduce sediment movement and protect habitat.	14. EMRI, EMRS, FOXR, TRIB, CWMUST, FRFISH, FUMUSS, MUSKRA, STRMAC, TRFISH, and TURTLE 15. FOXR, TRIB, FRFISH, FUMUSS, and TRFISH 16. EMRI, FOXR, TRIB, CWMUST, FUMUSS, MUSKRA, STRMAC, TRFISH, and TURTLE 17. TRIB, STRMAC, and TRFISH 18. EMRI, FOXR, TRIB, CWMUST, FUMUSS, MUSKRA, STRMAC, TRFISH, and TURTLE
5. Improve open water and nearshore fish habitat in lower Green Bay.	19. Implement Upper Fox, Wolf, and Lower Fox basin TMDLs. 20. Develop or restore important fish spawning and nursery habitats, such as rocky reefs, gravel, cobble, woody debris, and sandy areas for shoreline fish. 21. Improve fish spawning substrate at existing shoreline reef structures, such as Renard Island.	19. Nearly all fish and wildlife habitats and populations, especially OWGB, FOXR, SAVG, ANURAN, FRFISH, FWMUSS, CTM, SHFISH, STMAC, and TRFISH 20. COABIR, FRFISH, CTM, SHFISH, and TRFISH 21. COABIR and SHFISH
6. Expand and improve quality of emergent marsh (high energy) complexes.	22. Control invasive plant species (e.g., *Phragmites australis*, common reed; *Typha* × *glauca*, hybrid cattail) and maintain an appropriate mix of open water native emergent vegetation in west shore marshes. 23. Protect nest sites (e.g., tree cavities, snags, artificial nest boxes) for coastal birds (breeding) and establish nesting platforms for Osprey (*Pandion haliaetus*) and Bald Eagle (*Haliaeetus leucocephalus*). 24. Designate and protect sensitive areas at Dead Horse Bay, Longtail Point, Peters Marsh, Malchow-Olson tract, Point au Sable, Duck Creek Delta, and Duck Creek. 25. Create nest structures for wetland terns at Peters Marsh, Duck Creek, and Point au Sable and ensure	22. EMHE, ANURAN, BATS, COABIR, CWAQMA, CWMUST, COLWAT, LANDBI, MBBIRD, MUSKRA, CTM, SHFISH, TRFISH, TURTLE, WATERF, and WETTER 23. COABIR 24. EMHE, ANURAN, BATS, COABIR, CWAQMA, CWMUST, COLWAT, LANDBI, MBBIRD, MUSKRA, CTM,

	there are at least 20 breeding pairs of Black Tern (*Chlidonias niger*) and Forster's Tern (*Sterna forsteri*). 26. Establish safe road crossings at strategic areas for anurans and turtles. 27. Develop long-term management plan for sustaining emergent wetland habitat at sensitive wetlands during both high and low water periods.	SHFISH, TRFISH, TURTLE, WATERF, and WETTER 25. WETTER 26. ANURAN and TURTLE 27. EMHE, ANURAN, COABIR, CWAQMA, CWMUST, COLWAT, MBBIRD, MUSKRA, CTM, SHFISH, TRFISH, TURTLE, WATERF, and WETTER
7. Expand and improve quality of submerged aquatic vegetation.	28. Control introduced plant species (e.g., *Myriophyllum spicatum*, *Najas minor*, and *Potamogeton crispus*) and maintain extensive and high quality submerged aquatic vegetation (SAV) with native plants at Dead Horse Bay, Duck Creek, Peters Marsh, and Point au Sable. 29. Determine substrate needs for target plant species and then enhance and restore substrate condition. 30. Protect, maintain, and expand SAV biodiversity hotspots.	28. SAVG, ANURAN, CWAQMA, CWMUST, MBBIRD, MUSKRA, CTM, SHFISH, TURTLE, WATERF, and WETTER 29. SAVG 30. SAVG
8. Protect strategic coastal landscapes through land acquisition or conservation easement.	31. Establish conservation easement for Malchow-Olson Tract, unprotected wetlands in Duck Creek delta, and sections of the East River. 32. Designate sensitive coastal landscapes at UW-Green Bay's Bay Shore Woods and Beach, Barkhausen Waterfowl Preserve, Cat Island Chain Restoration Site, Point au Sable, and Longtail Point.	31-32. Impacted habitats and populations will depend on the habitats and areas of interest that are protected or purchased.
9. Protect large areas of quality wooded wetlands along AOC coast.	32. Control invasive woody plants in quality hardwood swamps at Barkhausen, Malchow-Olson Tract, Bay Beach Wildlife Sanctuary, UW-Green Bay's Bay Shore Woods and Beach, and Point au Sable. 33. Restore and expand habitats with native fruiting shrubs to improve stopover habitat for migratory land birds.	32. HASW, LANDBI, and WWBIRD 33. LANDBI
10. Re-establish freshwater mussel populations.	34. 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.	34. CWMUST, FWMUSS, and WATERF
11. Improve water quality in Green Bay, Fox	35. Promote best management practices and innovative nutrient management measures in Fox River watershed.	35-37. Nearly all fish and wildlife habitats and populations would benefit from improved water quality, especially SAVG,

River, and smaller tributaries.	36. Reduce unimpeded flow of toxins, nutrients, and sediments from urban/suburban storm water discharge pipes. 37. Implement effective non-point source pollution management plans in smaller watersheds and drainages.	ANURAN, FRFISH, FWMUSS, CTM, SHFISH, STMAC, and TRFISH
12. Designate and protect contiguous wetland habitat gradients at select AOC coastal sites.	38. Restore hydrologic gradient ranging from emergent marsh to shrub carr and to hardwood swamp at Peters Marsh, Malchow-Olson Tract, Duck Creek North, Point au Sable, and possibly Ken Euers Wildlife Area.	38. EMHE, HASW, SHCA, SSME, ANURAN, BATS, COABIR, CWAQMA, CWMUST, COLWAT, FUMUSS, LANDBI, MBBIRD, MUSKRA, CTM, SHOREBI, SHFISH, TURTLE, WATERF, WETTER, and WWBIRD
13. Enhance backwater habitats along Fox River for larval fish and invertebrates	39. Remove unwanted debris and reduce invasive species in backwater channel located under Leo Frigo Bridge on east side of Fox River. 40. Explore opportunities for creating backwater habitats in vicinity of De Pere Dam and possibly Ashwaubomay Park, National Railroad Museum, and St. Francis Park. 41. Evaluate the creation of islands in the Fox River to provide fish and wildlife habitat.	39. FOXR, EMRI, FRFISH, CTM, SHFISH, TURTLE 40. FOXR, EMRI, FRFISH, CTM, SHFISH, TURTLE 41. FRFISH, CTM, SHFISH, TURTLE
14. Restore rocky and gravel substrates in open Fox River channel at suitable locations.	42. Map and subsequently improve benthic substrate in vicinity of the De Pere Dam. 43. Establish multiple rock/gravel reefs at other sites in Fox River.	42. FOXR, FRFISH, CTM, FUMUSS, TRFISH 43. (same as a)
15. Control invasive species and improve shoreline habitat at inland wetlands near Green Bay and Fox River shoreline.	44. Establish native plants and construct or restore (if necessary) shallow topographic gradient at edges of small wetlands in AOC project area (within 1 km of shoreline) or along Duck Creek, East River, and other tributaries. 45. Work with local public works departments to improve habitat value of retention ponds and other artificial habitats in urban environment. 46. Identify and formally protect existing inland wetlands at Barkhausen Waterfowl Preserve, Duck Creek corridor, Bay Beach Wildlife Sanctuary, City of Green Bay landfill site, Point au Sable, and other areas.	44. EMIN, SHCA, OWIN, ANURAN, COABIR, CWAQMA, MBBIRD, WATERF, LANDB, COLWAT, SHFISH 45. (same as a) 46. (same as a)

16. Improve or restore floodplain deltas near river mouths at AOC tributaries	47. Expand protected zones surrounding lower reaches of Mahon Creek, Wequiock Creek, and other watercourses flowing into east shore of lower Green Bay. 48. Protect or restore backwater habitats near mouth of Fox River, Ashwaubenon Creek, and Dutchman's Creek. 49. Aggressively remove invasive species and restore low shorelines at river mouths of west shore tributaries.	47. TRIB, CWMUST, FUMUSS, STRMAC, TRFISH 48. TRIB, ANURAN, CWMUST, TRFISH 49. TRIB, FUMUSS, CWMUST, TRFISH

Table 2. Impacted priority habitats referenced in Table 1's list of recommended objectives and projects for the LGB&FR AOC above.

Priority Habitat	Code
Emergent Marsh (high energy coastal)	EMHE
Emergent Marsh (inland)	EMIN
Emergent Marsh (riparian)	EMRI
Emergent Marsh (roadside)	EMRS
Fox River Open Water	FOXR
Great Lakes Beach	GLBE
Green Bay Open Water	OWGB
Hardwood Swamp	HASW
Northern Mesic Forest	NMFO
Northern Wet-mesic Forest	NWMF
Open Water (inland)	OWIN
Other Forest	OTFO
Shrub Carr	SHCA
Southern Dry Mesic Forest	SDMF
Southern Sedge Meadow	SSME
Submergent Marsh	SAVG
Surrogate Grassland (old field)	SGOF
Surrogate Grassland Restored	SGRE
Tributary Open Water	TRIB

Table 3. Impacted priority populations referenced in Table 1's list of recommended objectives and projects for the LGB&FR AOC above.

Priority Population	Code
Anurans	ANURAN
Bald Eagle (winter)	BAEA
Bats	BATS
Coastal birds (breeding season)	COABIR
Coastal terrestrial macroinvertebrates	CTM
Coastal wetland aquatic macroinvertebrates	CWAQMA
Coastal wetland mustelids	CWMUST
Colonial waterbirds (breeding season)	COLWAT
Fox River fish	FRFISH
Freshwater unionid mussels	FUMUSS
Landbirds (migratory)	LANDBI
Marsh breeding birds	MBBIRD
Muskrat	MUSKRA
Piping Plover	PIPL
Shorebirds (migratory)	SHOREB
Shoreline fish	SHFISH
Stream macroinvertebrates	STRMAC
Tributary fish	TRFISH
Turtles	TURTLE
Waterfowl (migratory)	WATERF
Wetland terns	WETTER
Wooded wetland birds (breeding season)	WWBIRD

Appendix 10.1: Fox River

Written by Erin Giese and James Horn

<table>
<tr><td>**Location** (centroid)</td><td>Lat. 44.480266°, Lon. -88.042643°[1] (NAD 1983, UTM Zone 16N)</td></tr>
<tr><td>**Total Area** (ha)</td><td>526.34 ha</td></tr>
<tr><td>**Area Public Land** (ha)</td><td>The boundaries of the Fox River priority area are located within the coastal zone/waters of the Fox River and are thus entirely publicly owned. Depending on lake levels, parts of the shoreline may overlap with the boundaries of other priority areas.</td></tr>
<tr><td>**Area of Habitat Types Present (ha) and Percent of Each Habitat Type**</td><td>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&FR AOC)[2]. Habitat types within the Fox River 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 526.58 ha of natural habitat in the Fox River.
<table>
<tr><th>Habitat Type</th><th>Area (ha)</th><th>Percent</th></tr>
<tr><td>Emergent Marsh (High Energy Coastal)</td><td>0.04</td><td>0.01</td></tr>
<tr><td>Emergent Marsh (Inland)</td><td>0.02</td><td>0.00</td></tr>
<tr><td>Emergent Marsh (Riparian)</td><td>0.57</td><td>0.11</td></tr>
<tr><td>Fox River Open Water</td><td>520.72</td><td>98.89</td></tr>
<tr><td>Great Lakes Beach</td><td>0.01</td><td>0.00</td></tr>
<tr><td>Hardwood Swamp</td><td>0.84</td><td>0.16</td></tr>
<tr><td>Other Forest</td><td>0.23</td><td>0.04</td></tr>
<tr><td>Submergent Marsh</td><td>3.61</td><td>0.69</td></tr>
<tr><td>Surrogate Grassland (Old Field)</td><td>0.22</td><td>0.04</td></tr>
<tr><td>Tributary Open Water</td><td>0.24</td><td>0.04</td></tr>
<tr><td>Wasteland</td><td>0.09</td><td>0.02</td></tr>
</table>
Disclaimer! *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 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 2017. Great Lakes water levels were much higher in 2017 than in July 2015.*</td></tr>
<tr><td>**General Description**</td><td>The Fox River is a third order stream that flows northeast and forms the basis of the Lower Fox River basin, which is 1,654 km^2 in size[3]. The lower Fox River starts from Lake Winnebago and empties into Green Bay, which is the western arm of Lake Michigan. The Fox River priority area only includes the Fox River open water from the mouth of the Fox River to the De Pere Dam. In order for small boats to travel upstream past the De Pere Dam, they must travel through the De Pere Locks. The shipping channel in the lower bay of Green Bay continues down the Fox River roughly 6.5 km</td></tr>
</table>

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[1] File "AOC_PriorityAreas.v09_20171212.shp"
[2] LGB&FR AOC 2015 habitat field mapping effort
[3] WDNR's Lower Fox River basin webpage: http://dnr.wi.gov/topic/Watersheds/basins/lowerfox/

	upstream to the south with depths of up to 7.32 km (24 ft) in the river[4]. Waters along the eastern and western shorelines of the Fox River range from 0.30-1.22 km (1-4 ft) deep[4]. The East River, Ashwaubenon Creek, and Dutchman Creek are smaller second order streams that empty into the Fox River. When the Fox River empties into the lower bay, the water currents move in a counterclockwise direction starting by traveling up the eastern shore of the bay to Sturgeon Bay, at which point the currents turn west[5]. Seiche can affect shorelines along the Fox River for up to 9.66 km (6 mi) upstream[6]. Sediments consist of sand and clay[7]. Unfortunately, water quality in the lower bay and Fox River has been poor for decades. The LGB&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 and has a long history of pollution. Since 2009, the Fox River Cleanup Project has been working to dredge up historic polychlorinated biphenyls (PCB) in 20.92 km (13 mi) that are found in Fox River sediment[8]. Waters within the LGB&FR AOC regularly report high concentrations of total phosphorus, total suspended solids, nitrates/nitrates, and toxic chemicals, leading to poor overall water quality[9,40]. It can also be turbid and experience summer and late fall blooms of harmful algae[9]. Fox River waters often contain low levels of oxygen, especially in the summer, which can be problematic and deadly for fish[10]. The land surrounding the Fox River between the De Pere Dam and mouth of the Fox River is heavily industrialized and urbanized, creating a significant amount of impervious surfaces, which contributes to the nutrient runoff problem. Despite water quality issues, a great number of wildlife still use the Fox River, especially fish species, and it is extremely well studied particularly in terms of fish and water quality. Over the past several decades, scientists from agencies, non-profit organizations, universities, and other organizations have conducted dozens of research projects and collected data on fish, water quality, odonates, bats, birds, anurans (frogs + toads), and plants. Like other Great Lakes, large ships and freighters regularly use the bay and Fox River shipping channel for transporting goods, such as coal, limestone, salt, wood products, and other products[11]. Residents and visitors of Green Bay regularly use the waters of the lower bay and Fox River 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.
Special Features	• Three streams empty into the lower Fox River below the De Pere Dam, namely Ashwaubenon Creek and Dutchman Creek on the west shore and the East River on the east shore. • Features critical spawning habitat below the De Pere Dam for lake sturgeon (*Acipenser fulvescens*), walleye (*Sander vitreus*), smallmouth bass (*Micropterus dolomieu*), and lake whitefish (*Coregonus clupeaformis*). This area is known for being a world-class walleye fishery[12,13].

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[4] 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

[5] Klump et al. 1997: Sedimentary phosphorus cycling and a phosphorus mass balance for the Green Bay, Lake Michigan ecosystem

[6] Bertrand et al. 1976: "The Green Bay Watershed: Past/Present/Future

[7] Dorney 1975: The vegetation pattern around green Bay in the 1840s as related to geology, soils, and land use by Indians with a detailed look at the Townships of Scott, Green Bay, and Suamico

[8] Fox River Cleanup Project Webpage: http://foxrivercleanup.com/

[9] Qualls et al. 2013: State of the Bay 2013: http://www.seagrant.wisc.edu/Home/Topics/HabitatsandEcosystems/Details.aspx?PostID=1840

[10] Howlett 1974: The rooted vegetation of west Green Bay with reference to environmental change

[11] Port of Green Bay Website: http://www.portofgreenbay.com/

[12] World-class walleye fishery: http://www.wbay.com/content/news/Tagging-Study-Helps-Answer-Wheres-Walleye-418000233.html

[13] Top 10 Midwest Walleye Fisheries: http://www.in-fisherman.com/rigged-ready/mw/top-10-midwest-walleye-fisheries/

	• Provides significant open water and nearshore fish habitat. • Provides habitat for odonates (dragonfly/damselfly)[14]. • Provides relatively open foraging habitat for bats[15]. • Contains two submergent marshes located along the eastern shoreline by the Fox Point Boat Launch and in the outer reaches and mouth of Ashwaubenon Creek adjacent to the Fox River on the western Fox River shoreline. • Important waterfowl migratory bird stopover site at the De Pere Dam and the mouth of the Fox River[16].
Natural Habitat Communities and Significant Plants (ordered in terms of ecological importance and size/amount)	Nearly 99% of the Fox River priority area consists of **Fox River open water** (520.72 ha) with little to no plant life, with the exception of two patches of **submergent marsh** (3.61 ha total) that are located along the eastern shoreline of the Fox River by the Fox Point Boat Launch and in the outer reaches and mouth of Ashwaubenon Creek adjacent to the western shore of the Fox River[2,17]. The submergent marsh on the eastern shoreline of the Fox River is dominated by sago pondweed (*Stuckenia pectinata*) and slender waterweed (*Elodea nuttallii*). Other native species that were present but rare were longleaf pondweed (*Potamogeton nodosus*) and leafy pondweed (*Potamogeton foliosus*) with invasive Eurasian watermilfoil (*Myriophyllum spicatum*). The submergent marsh located at the mouth of Ashwaubenon Creek had wild celery (*Vallisneria americana*), leafy pondweed, longleaf pondweed, sago pondweed, coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*), and water stargrass (*Heteranthera dubia*).

Significant Animals	**Birds**:
	• >130 bird species have been reported in recent years using the Fox River or terrestrial/riparian habitats along the Fox River[18]:
	  o Ducks, waterfowl, and waterbirds that use the Fox River during migration, summer, and/or winter, including, but not limited to:
	    ▪ Based on recent 2016-2017 LGB&FR AOC Migratory Waterfowl Study; surveys done by Tom Prestby:
	      • Congregate in relatively large groups during migration at the De Pere Dam:
	        o Ring-billed Gull (*Larus delawarensis*)
	        o Herring Gull (*Larus smithsonianus*)
	        o Mallard (*Anas platyrhynchos*), regional priority species from the North American Waterfowl Management Plan
	      • Congregate in small numbers:
	        o Canada Goose (*Branta canadensis*), regional priority species from the North American Waterfowl Management Plan
	        o Double-crested Cormorant (*Phalacrocorax auritus*)
	        o American White Pelican (*Pelecanus erythrorhynchos*), a state special concern species
	        o Common Merganser (*Mergus merganser*)
	        o Common Goldeneye (*Bucephala clangula*), a state special concern species

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[14] Willson Gaul's LGB&FR AOC 2016 odonate surveys

[15] Jeremiah Shrovnal's LGB&FR AOC 2016 bat surveys

[16] Epstein et al. 2002

[17] LGB&FR AOC Submerged Aquatic Vegetation Mapping; led by Dr. Amy Wolf and Dr. James Horn

[18] LGB&FR AOC Biota Database: file "AOCBiota_DB_ShareableVersion_20171213.accdb"

        - Great Egret (*Ardea alba*), state threatened and listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern
    - In recent years, according to the Wisconsin Breeding Bird Atlas II Project[19], at least two Cliff Swallow (*Petrochelidon pyrrhonota*) colonies nest under bridges along the Fox River; Barn Swallows (*Hirundo rustica*) nest under the Main Avenue bridge next to the De Pere Dam. Chimney Swift (*Chaetura pelagica*), Peregrine Falcon (*Falco peregrinus*), Common Grackle (*Quiscalus quiscula*), Red-winged Blackbird, Mallard, Canada Goose, Rock Pigeon (*Columba livia*), and many other birds nest in coastal and terrestrial habitats along the Fox River.
    - Songbirds and landbirds use the narrow terrestrial habitats along the Fox River Trail during migration.

Fish:

- >80 fish species have been recorded in the pelagic zone of the lower bay, though not all have been reported in the Fox River, including[18]:
    - Lake sturgeon (*Acipenser fulvescens*), globally vulnerable and state special concern species; spawn below the De Pere Dam
    - Walleye (*Sander vitreus*), spawn below the De Pere Dam; other spawning reef habitat improvements have been made by Voyageur Park, Ashwaubomay Memorial River Park, and Fox Point Boat Launch
    - Lake whitefish (*Coregonus clupeaformis*), spawn below the De Pere Dam
    - Bluegill sunfish (*Lepomis macrochirus*)
    - Gizzard shad (*Dorosoma cepedianum*)
    - Smallmouth bass (*Micropterus dolomieu*), spawn below the De Pere Dam
    - Longnose gar (*Lepisosteus osseus*)
    - Muskellunge (*Esox masquinongy*), spawning habitat on the eastern shoreline of the Fox River north of Voyager Park and south of Mason Street
    - Northern pike (*Esox lucius*)
    - Smallmouth bass (*Micropterus dolomieu*)
    - Yellow perch (*Perca flavescens*)

Mammals:

- 10 species of mammals have been reported using areas along the Fox River:
    - Big brown bat (*Eptesicus fuscus*), state threatened
    - Eastern red bat (*Lasiurus borealis*), globally vulnerable
    - Hoary bat (*Lasiurus cinereus*)
    - Little brown bat (*Myotis lucifugus*), globally vulnerable and state threatened
    - Silver-haired bat (*Lasionycteris noctivagans*), globally vulnerable and state special concern species
    - Virginia opossum (*Didelphis virginiana*)
    - White-tailed deer (*Odocoileus virginianus*)
    - Eastern chipmunk (*Tamias striatus*)
    - Eastern cottontail (*Sylvilagus floridanus*)
    - Eastern gray squirrel (*Sciurus carolinensis*)

Amphibians:

- American toad and green frog have been recorded using emergent marsh habitat along the Fox River shoreline in 2015[18]

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[19] Wisconsin Breeding Bird Atlas II Project (2015-2019): https://wsobirds.org/atlas

	Reptiles:
	- Only one reptile has been reported using the Fox River, namely a spiny softshell turtle (*Apalone spinifera*), in 2015 though other turtles and snakes like also use the Fox River and/or adjacent terrestrial habitats
	
	Arthropods:
	- A few mayfly species were reported in 1998 along the Fox River[18]:
	  - E.g., *Hexagenia limbata*, *Baetis flavistriga*, *Labiobaetis frondalis*, etc.
	- Eight species of odonates (dragonfly/damselfly) were recorded using areas along the Fox River in 2016:
	  - Blue dasher (*Pachydiplax longipennis*)
	  - Blue-fronted dancer (*Argia apicalis*)
	  - Common green darner (*Anax junius*)
	  - Eastern amberwing (*Perithemis tenera*)
	  - Eastern forktail (*Ischnura verticalis*)
	  - Orange bluet (*Enallagma signatum*)
	  - Russet-tipped clubtail (*Stylurus plagiatus*)
	  - Slender spreadwing (*Lestes rectangularis*)

Habitat Quality	Overall, the ecological quality of the entire lower bay of Green Bay and Fox River is relatively poor. The LGB&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. 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[9]. 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)[9]**.** Nitrates received a "fair-good" rating with a deteriorating trend. Ammonia earned a "good" rating with an unchanging trend[9]. The lower bay also experiences summer and late fall blooms of harmful algae[9]. Between 1986 and 2013, NEW Water reported that the LGB&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[20].

Significant Invasive Species Issues	**Invasive Plant Species**: Each of these species outcompetes and crowds out native plants[2,17]:
	- Eurasian water-milfoil (*Myriophyllum spicatum*)
	  - Sparsely found within some of the submergent marshes
	- Common reed (*Phragmites australis*)
	  - Occurs along stretches of emergent marsh (riparian); in recent years, 0.51 ha (1.25 ac) in the emergent marsh (riparian) located at Ashwaubomay Memorial Park was treated[44]
	
	Invasive Animal Species:
	- *Fish*[18] – These fish species have been reported in the pelagic zone of the lower bay:

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[20] 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

	○ Alewife (*Alosa pseudoharengus*)[21] ▪ Poses a threat to native fish species by consuming zooplankton and disturbing the natural food web; not currently being managed ○ Common carp (*Cyprinus carpio*)[22] ▪ Destroy vegetation by uprooting plants and increasing cloudiness of water; not currently being managed ○ Rainbow smelt (*Osmerus mordax*)[23] ▪ Negatively affect uncommon to rare native fish species; not currently being managed ○ Round goby (*Neogobius melanostomus*)[24] ▪ Prey on small native fish and eggs (e.g., darters) and outcompete similarly sized native fish; not currently being managed ○ White perch (*Morone americana*)[25] ▪ Prey on native fish eggs, such as walleye; not currently being managed • *Birds* ○ House Sparrow (*Passer domesticus*) ▪ May pose a small threat to some native species by outcompeting them for food; tend to inhabit developed areas; not currently being managed ○ European Starling (*Sturnus vulgaris*) ▪ Poses some threat to native species, particularly cavity nesters (e.g., Tree Swallow), by outcompeting them and occupying potential nest sites; not currently being managed ○ Brown-headed Cowbird (*Molothrus ater*) ▪ Poses threat to some native species because they lay eggs in native bird species' nests through brood parasitism. ○ The exotic species, Rock Pigeon (*Columba livia*), generally does not significantly affect native birds because they tend to inhabit human areas (e.g., developed or agricultural areas) where natives do not frequently nest (e.g., on ledge under bridge or overpass).
Management and Restoration Recommendations	• Use The Nature Conservancy's fish passage GIS tool to identify and remove barriers that, if removed, would provide access to potential spawning areas. • Improve substrate (including gravel, riffles, and pool habitat) and reduce sediment pollution. • Remove unwanted debris and reduce invasive species in backwater channel located under Leo Frigo Bridge on east side of Fox River. • Explore opportunities for creating backwater habitats in vicinity of De Pere Dam and possibly Ashwaubomay Park, National Railroad Museum, and St. Francis Park.

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[21] 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.

[22] 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.

[23] 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.

[24] 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.

[25] 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.

	• Evaluate the possibility of creating islands in the Fox River to provide fish and wildlife habitat. • Map and subsequently improve benthic substrate in vicinity of the De Pere Dam. • Protect or restore backwater habitats near mouth of Fox River, Ashwaubenon Creek, and Dutchman's Creek. • Establish multiple rock/gravel reefs at other sites in Fox River. • Protect and enhance riparian habitats in parts of the East River. • Reduce magnitude of storm surges (flashiness) by creating or maintaining upstream vegetation buffers and mitigating inputs from stormwater drainages. • Stabilize falling banks to reduce sediment movement and protect habitat. • Implement Upper Fox, Wolf, and Lower Fox basin TMDLs. • Develop or restore important fish spawning and nursery habitats, such as rocky reefs, gravel, cobble, woody debris, and sandy areas for shoreline fish. • Control invasive plants (e.g., *Phragmites*, Eurasian water-milfoil). • Promote best management practices and innovative nutrient management measures in Fox River watershed. • Reduce unimpeded flow of toxins, nutrients, and sediments from urban/suburban storm water discharge pipes. • Implement effective non-point source pollution management plans in smaller watersheds and drainages.
Reference Links and Documents	**Web Links**: • Fox River PCB Clean-up Project: http://foxrivercleanup.com/ • Fox 11 video on Green Bay poor water quality (including interview with Dr. Val Klump): ○ http://fox11online.com/news/fox-11-investigates/fox-11-investigates-poor-water-quality-plaguing-green-bay • NEW Water's Aquatic Monitoring Program: http://newwater.us/programs-initiatives/aquatic-monitoring-program/ • WDNR's Surface Water Data Viewer: https://dnrgis.wi.gov/H5/?Viewer=SWDV • NOAA's Lake Level Viewer: https://coast.noaa.gov/digitalcoast/tools/llv.html • TMDL and Watershed Management Plan for Total Phosphorus and Total Suspended Solids in the Lower Fox River Basin and Lower Green Bay: http://www.uwgb.edu/watershed/REPORTS/Related_reports/TMDLs/LFR_TMDL_EPA_Submittal_Aug_2011.PDF • "Dead zones haunt Green Bay as manure fuels algae blooms" (article by the *Journal Sentinel*): http://archive.jsonline.com/news/wisconsin/dead-zones-haunt-green-bay-as-manure-fuels-algae-blooms-die-offs-b99344902z1-274684741.html/ • Lower Fox Demonstration Farms Network: implementing farming best management practices in the lower Fox River watershed: https://fyi.uwex.edu/foxdemofarms/about-us/where-we-work/ • Nonpoint Source Control Plan for the Duck, Apple, and Ashwaubenon Creeks Priority Watershed Project: http://dnr.wi.gov/topic/nonpoint/documents/9kep/Duck_Apple_Ashwaubenon_Creeks-Plan.pdf • 1845 Map of Green Bay: http://s3.amazonaws.com/labaye/data/1845%20Head%20Of%20Green%20Bay.pdf • WDNR Fisheries Biologists: http://dnr.wi.gov/topic/fishing/people/fisheriesbiologists.html • U.S. Fish and Wildlife Service Fisheries Programs: https://www.fws.gov/midwest/greenbayfisheries/programs.html

	Reference Documents: - 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. ○ https://dc.uwm.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=2047&context=etd - 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. - 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. Journal of Great Lakes Research 41:1024-1036. - 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. Canadian Journal of Fisheries and Aquatic Sciences 54:10-26. - 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. - Wisconsin Department of Natural Resources. 2014. Green Bay Planning Group Master Plan. Technical Report PUB-LF-075.
Site History (e.g., original vegetation, past conservation projects)	In the early 1630s, Frenchman Jean Nicolet first arrived in lower Green Bay when it was primarily inhabited by Native American tribes[26]. Lower Green Bay consisted of large beds of wild rice (*Zizania* sp.) and wild celery (*Vallisneria americana*), extensive emergent marsh (*Schoenoplectus* sp., cattail), sedge meadows (*Calamagrostis canadensis*), shrub carr (e.g., *Cornus* spp., *Salix* spp.), swamps, and wet conifer forest (black spruce [*Picea mariana*], balsam fir [*Abies balsamea*])[27,28,29,30,31]. Between the late 1600s and 1800s, European fur trade, duck hunting, fishing, logging, shipping, and agriculture were important early industries in lower Green Bay[32,33,34]. In the early 1800s, there were a few small settlements and farms of Europeans and Native Americans in the lower Bay[33]. Similar to the fur trade and logging, commercial fishing was an important industry in Green Bay, in which most fishermen primarily harvested whitefish, lake trout, and lake herring[9,35]. Other fish caught in Brown County in 1888 included perch, pike pickerel, suckers, catfish, muskellunge, and many others[9,36]. Unfortunately, overfishing and other significant anthropogenic changes, such as water pollution caused by the paper industry, led to the decline of many fish species[9,35].

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[26] Jean Nicolet: French Explorer. By The Editors of Encyclopaedia Britannica. Available: https://www.britannica.com/biography/Jean-Nicolet (accessed on 24 Oct 2016).

[27] Arthur C. Neville's Map of Historic Sites on Green Bay, Wisconsin 1669-1689. Available: http://s3.amazonaws.com/labaye/data/Bay%20Settle ment%20Map%20WI%20Historical%20Bulletin%201926.pdf (accessed on 24 Oct 2016).

[28] 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).

[29] 1845 Chart of Green Bay. Available http://s3.amazonaws.com/labaye/data/1845%20Chart%20of%20Green%20Bay.pdf (accessed on 24 Oct 2016).

[30] 1820s Fox River Military Road Map to Ft. Crawford. Available: http://s3.amazonaws.com/labaye/data/1820s%20Fox%20River%20Military%20 Road%20Map%20to%20Ft.%20Crawford.pdf (accessed on 24 Oct 2016).

[31] UW-Green Bay personal communication with Thomas Erdman.

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

[33] 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).

[34] 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).

[35] Qualls et al. (2013) cited Kraft, C. 1982. Green Bay's Yellow Perch Fishery. Wisconsin Sea Grant Publication. WIS. SG.82-725.

[36] 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.

Historically, the mouth of the Fox River consisted of extensive meadows and marshes, though even wild rice was found along the Fox River[7,29,37]. Sauk Native Americans lived near the mouth of the Fox River until 1733, at which point they moved south (fact from Neville Public Museum)[7]. Villages, campsites, and burial sites occurred along the Fox River from both the Sauk and Fox Native American Tribes[7]. Upland, riparian vegetation along the lower Fox River consisted of beech (*Fagus* sp.), maple (*Acer* sp.), basswood (*Tilia* sp.), and oak (*Quercus* sp.)[7]. Between the present day De Pere Dam and the Mason Street bridge, there used to be extensive emergent marsh vegetation. In fact, this vegetation is visible on the 1938 Brown County air photo, especially the large, open section of water on the western side of the Fox River by the De Pere Dam. This area contained submergent marsh and cattail (*Typha* sp.) beds, including floating mats, which were heavily used by fish and nesting birds (e.g., Least Bittern [*Ixobrychus exilis*], Blue-winged Teal [*Anas discors*], Marsh Wren [*Cistothorus palustris*], rails)[31]. These emergent marshes along the Fox River are still visible in the 1960 Brown County air photo. This area also provided important migratory bird stopover habitat[31].

Because of extensive shallow areas in the lower bay and miles-long sand bars, ship navigation was extremely challenging and in some cases nearly impossible[38]. 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[38,39]. Construction began in May the following year and was quickly finished by September 1867[38]. 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)[38]. By the early 1930s, the channel was widened again and increased depth to 6.71 m (22 ft)[38]. Today, the main channel in the bay is anywhere between 7.32 m (24 ft) and 7.92 m (26 ft) and around 152.4 m (500 ft) wide.

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

- 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&FR AOC, including sites in the Fox River[40]. They survey for ichthyoplankton, carp, macroinvertebrates, and nearshore fishes[40]. In the Fox River, they also conduct larval Coregonid surveys (i.e., whitefishes)[40].
- NEW Water leads a long-term aquatic monitoring program with multiple sampling locations within the LGB&FR AOC as well as other parts of the bay of Green Bay and Fox River. They collect data on water temperature, dissolved oxygen, pH, phosphorus, nitrogen, turbidity, total suspended solids, and many others[41].
- WDNR juvenile whitefish assessments and lake sturgeon sampling in the Fox River[43].
- WDNR walleye and musky management by Steve Hogler, Rod Lange, and Steve Surendonk[43].
- WDNR Lower Fox River IBI Surveys between the De Pere Dam and the bay (2015)[43].

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[37] Original 1800s PLSS Surveys: converted from tier/range/sections into transects by Ellie Roark

[38] *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

[39] U.S. Army Corps of Engineers Map of the shipping channel from 1898 and 1898; provided by Tom Erdman

[40] Green Bay Fish Working Group Annual Meetings on 20 March 2015, 6 January 2016, and 4 January 2017

[41] NEW Water Aquatic Monitoring Program: http://newwater.us/programs-initiatives/aquatic-monitoring-program/

	• WDNR musky spawning surveys on the Fox River. • Since the early 2000s, the Fox River Cleanup Project has been working to dredge up historic polychlorinated biphenyls (PCB) in 20.92 km (13 mi) that are found in Fox River sediment[8]. • Brown County's young-of-the-year northern pike surveys in Ashwaubenon Creek, Dutchman Creek, and the East River (Chuck Larscheid)[44]. • WDNR Fox River Fish Index Surveys (fall) for walleye recruitment between the De Pere Dam and the bay, since 1987, led by Steve Hogler[43]. • In 2014-2016, UW-Milwaukee's Dr. Jerry Kaster and graduate student Christopher Groff released 120 million eggs of *Hexagenia* (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[40]. • 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&FR AOC[17]. • The Nature Conservancy is currently leading an effort to identify fish passage barriers in the LGB&FR AOC and other areas. • In 2016-2017, under the guidance of CCB's Dr. Howe, Dr. Wolf, and Erin Giese, Tom Prestby surveyed migratory waterfowl within the LGB&FR AOC and mapped rafts. Within the Fox River, one survey location is at the mouth of the Fox River and the other is at the De Pere Dam. • Multiple locations along the Fox River were surveyed for birds and anurans in 2015 as a part of a larger effort in the LGB&FR AOC; surveys coordinated by CCB's Erin Giese, Dr. Howe, and Dr. Wolf. • Fox River walleye habitat improvement projects at Voyageur Park, Brown County Fairgrounds, and Fox Point Marina on the Fox River, 1986-1994[43]. • *Phragmites* management at Ashwaubomay Memorial River Park[44]. • Lower Fox River Basin Integrated Management Plan, 2011[43]. • Lower Fox River Volunteer TMDL Monitoring at Dutchman Creek, Ashwaubenon Creek, and the East River and a targeted watershed assessment (WDNR, 2015). • Dr. Val Klump has spent a significant part of his career studying Green Bay water quality issues. ○ http://waterbase.uwm.edu/docs/Klump_Fermanich_2017_FinalReport_NA10NOS4780139_26Jan2017.pdf • Recently, FWS' Steve Choy has led a project aimed to draft up habitat restoration designs in the Fox River near the De Pere Dam. • Glacierland RC&D (2013-2016) investigated phosphorus reductions through grass-based farming and managed grazing[43]. • The U.S. Environmental Protection Agency conducted a PCB transport study in the Fox River in 1995. • UW-Green Bay graduate student, Tony Rieth, and his major advisor, Dr. John Stoll, conducted an economic feasibility study of agricultural land conversion to switchgrass in the lower Fox River watershed[43]. • 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[42]. • The Northeast Wisconsin Land Trust's Green Bay and Lower Fox Project, which involves identifying high priority land parcels that could potentially improve water quality through conservation easements, etc.[43]. • Green Bay Ecosystem Modeling, UW-Extension's Chad Cook[43]. • Management Analysis Tool, which looks at how climate and landscape conservation can impact Green Bay water quality (Dr. Kevin Fermanich)[43]. • WPS coal cleanup near the mouth of the East River[44].

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[42] Lower Fox Demonstration Farms Network: https://fyi.uwex.edu/foxdemofarms/about-us/where-we-work/
[43] AOC Conservation Project Catalogue.
[44] LGB&FR AOC Stakeholder's Meeting in June 2015.

	The Fox River provides significant and in most cases rather critical habitat for many fish species, odonates, waterfowl, waterbirds, bats, anurans, and reptiles. Water quality is relatively poor due to high nutrient and sediment loadings in the Fox River and pollution. Like other bodies of water, the bay and Fox River have experienced (and in some cases still experience) harmful algal blooms, fish kills, and avian botulism[9,45,46,47]. 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 and the Fox River. Restoration of shoreline fish spawning and nursery habitats, such as rocky reefs, gravel, cobble, woody debris, and sandy areas, are needed. Backwater habitats near mouth of Fox River, Ashwaubenon Creek, and Dutchman's Creek should be protected or restored. Efforts should continue to be made to re-introduce *Hexagenia* in the bay. To improve water quality, implementing best management practices for agriculture and TMDLs for the Upper Fox, Wolf, and Lower Fox basins will be necessary. There is no doubt that a significant amount of work is needed in the bay and the Fox River, 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.

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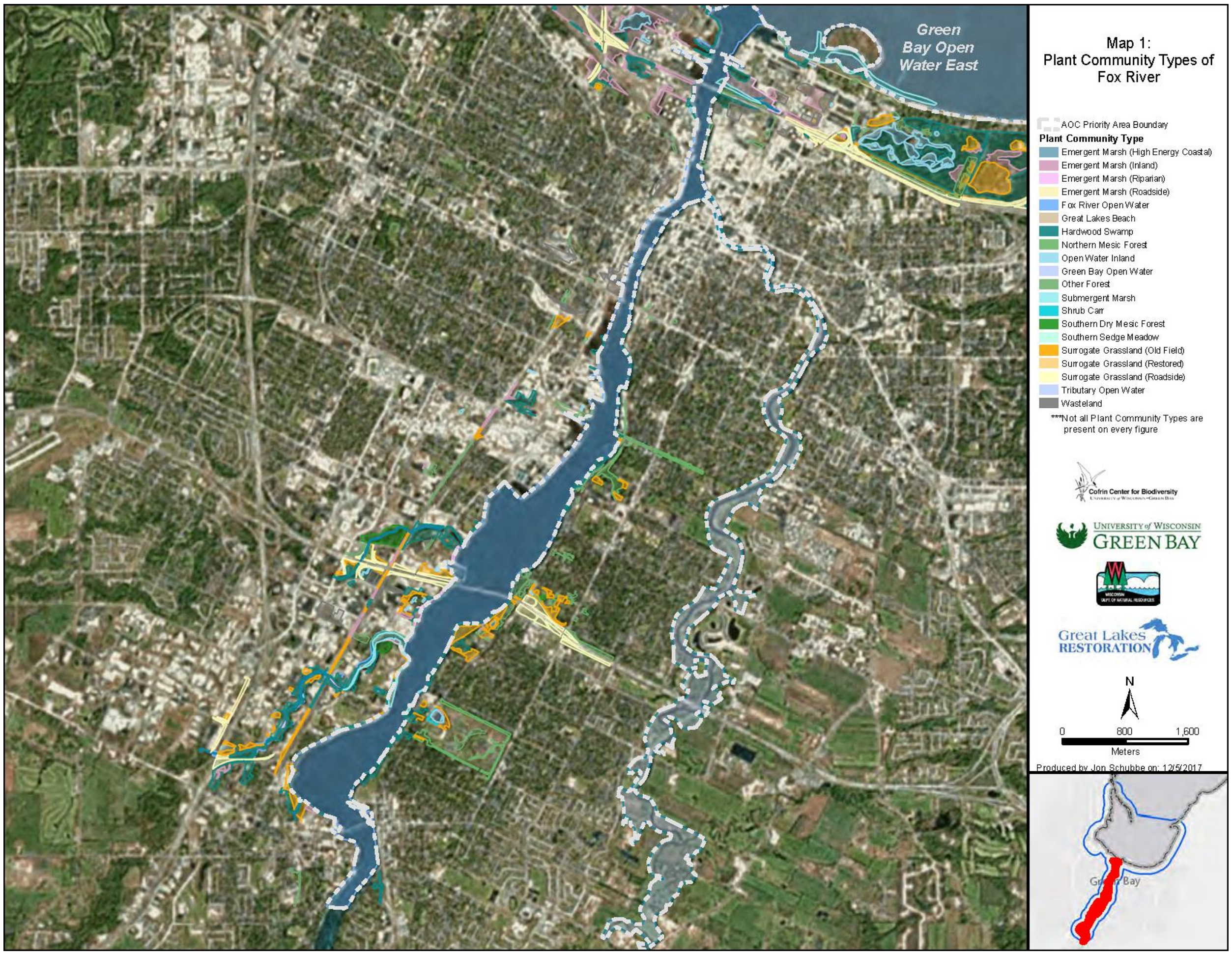
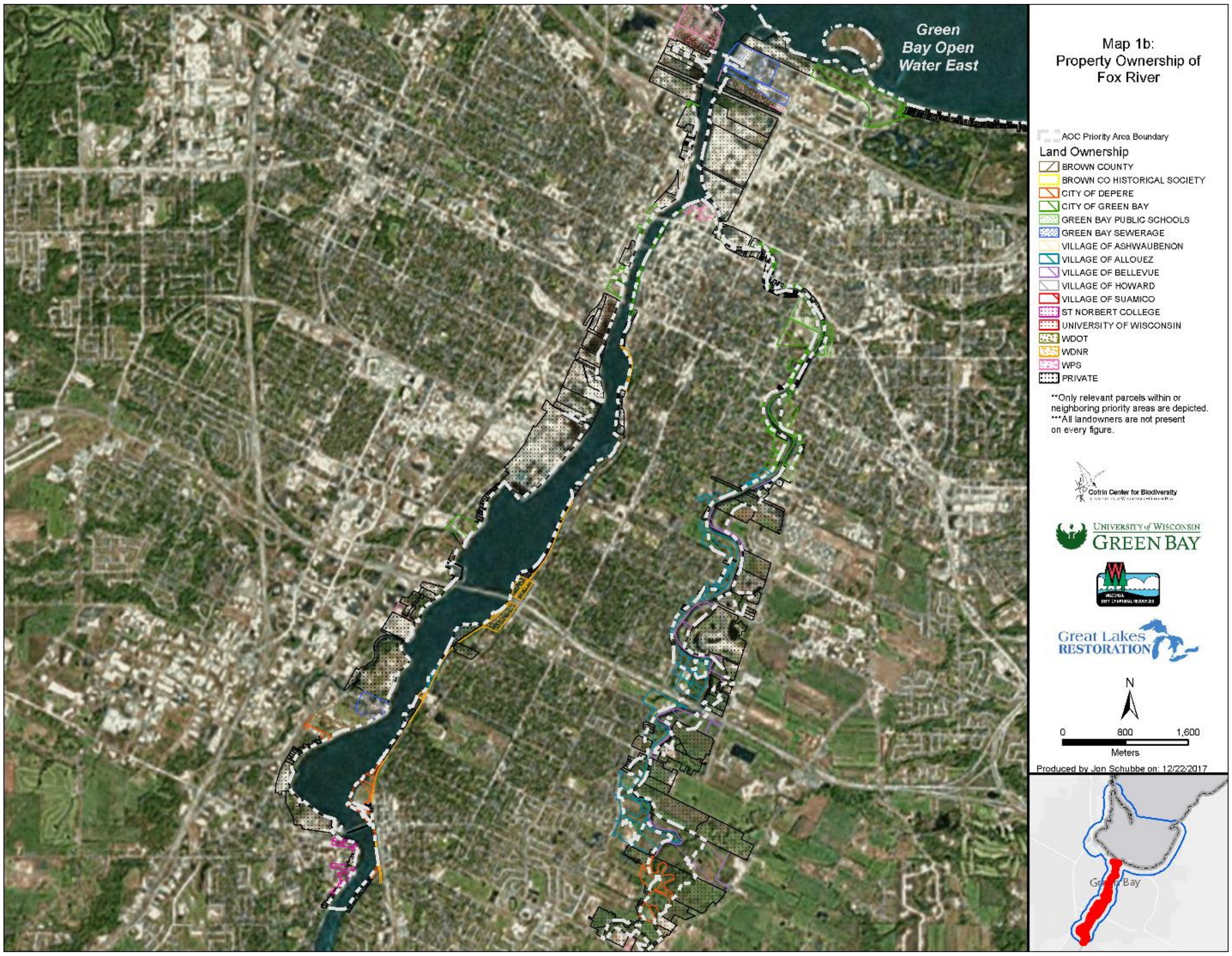
[45] Silliman et al. 2001: "A hypothesis for the origin of perylene based on its low abundance in sediments of Green Bay, Wisconsin"

[46] Smith et al. 1988: "Estuary Rehabilitation: The Green Bay Story"

[47] Brand et al. 1983: Waterbird mortality from botulism type E in Lake Michigan: an update"

Map of Fox River 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 the Fox River. Map made by UW-Green Bay’s Jon Schubbe.

Photograph of the Fox River facing the De Pere Dam (back), Abbey Pond (left), and Ashwaubomay Memorial River Park (center). Photograph taken by Erin Giese on 2 December 2016 facing southwest.

Photograph of the mouth of the Fox River facing the Leo Frigo Bridge (center) and Renard Island (left). Photograph taken by Erin Giese on 2 December 2016 facing east/southeast.

Photograph of the Fox River facing the Mason Street Bridge (left) and railroad crossing (right/central). Photograph taken by Erin Giese on 2 December 2016 facing southeast.

Photograph of the Fox River south of the De Pere Dam in Little Rapids facing the Lost Dauphin Park (bottom). Photograph taken by Erin Giese on 2 December 2016 facing south.

Appendix 10.2: Green Bay Open Water East

Written by Erin Giese and James Horn

<table>
<tr><td>**Location** (centroid)</td><td>Lat. 44.557768°, Lon. -87.951764°[1] (NAD 1983, UTM Zone 16N)</td></tr>
<tr><td>**Total Area** (ha)</td><td>3,207.07 ha</td></tr>
<tr><td>**Area Public Land** (ha)</td><td>The boundaries of the Green Bay Open Water East 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 east shore (e.g., Bay Shore Woods and Beach) may overlap with the boundaries of the Green Bay Open Water East priority area.</td></tr>
<tr><td>**Area of Habitat Types Present (ha) and Percent of Each Habitat Type**</td><td>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&FR AOC)[2]. Habitat types within Green Bay Open Water East 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 3,207.07 ha of natural habitat in Green Bay Open Water East.
<table>
<tr><th>Habitat Type</th><th>Area (ha)</th><th>Percent</th></tr>
<tr><td>Emergent Marsh (High Energy Coastal)</td><td>4.20</td><td>0.13</td></tr>
<tr><td>Great Lakes Beach</td><td>5.94</td><td>0.19</td></tr>
<tr><td>Green Bay Open Water</td><td>3182.92</td><td>99.25</td></tr>
<tr><td>Other Forest</td><td>0.18</td><td>0.01</td></tr>
<tr><td>Submergent Marsh</td><td>13.83</td><td>0.43</td></tr>
</table>
Disclaimer! 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.</td></tr>
<tr><td>**General Description**</td><td>The Green Bay Open Water East priority area consists of the eastern 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 West priority area by the shipping channel, though there are some distinct differences between the eastern and western halves of the bay. Shallower areas along the eastern shoreline, Point Sable Bar (drowned sandbar that extends from Point Sable nearly reaching Longtail Point), and where Grassy Island used to reside (former island across from present day Cat Island Wave Barrier and by Lone Tree Island) can range from 0.30 m to 1.83 m (1-6 ft) in depth[3,4]. The remainder of Green Bay Open Water East can get as deep as 3.05 m (10 ft) with the exception of the shipping channel, which can be up to 7.32-7.92 m (24-26 ft) deep[3,4]. The Fox River empties into the lower bay, and the water currents move in a counterclockwise direction starting by</td></tr>
</table>

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[1] File "AOC_PriorityAreas.v09_20171212.shp"

[2] LGB&FR AOC 2015 habitat field mapping effort

[3] Depths based on 1988 NOAA bathymetry survey

[4] 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

	traveling up the eastern shore to Sturgeon Bay, at which point the currents turn west[5]. Sediments largely consist of sand and silt[6]. Unfortunately, water quality in the lower bay has been poor for decades. The LGB&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&FR AOC regularly report high concentrations of total phosphorus, total suspended solids, nitrates/nitrates, and toxic chemicals, leading to poor overall water quality[7,48]. It can also be turbid and experience summer and late fall blooms of harmful algae[7]. Despite water quality issues, a great number of fish and wildlife still use the lower bay's pelagic zone. The Green Bay Open Water East (and West) priority area is extremely well studied and may in fact be one of the most studied priority areas in the LGB&FR AOC. Over the past several decades, scientists from agencies, non-profit organizations, universities, 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.
Special Features	• Provides critical open water and nearshore fish habitat (e.g., woody debris) as well as spawning reefs around Renard Island, the McDonald Marina (eastern shore of the mouth of the Fox River), and Joliet Park. • Provides habitat for open water and nearshore aquatic invertebrates, including freshwater mussels, aquatic insects, arthropods, annelids, etc. • Contains Great Lakes beach, which is rare to both the state of WI and the LGB&FR AOC, and nearshore and submergent marsh habitats. • Important waterfowl migratory bird stopover site[8].
Natural Habitat Communities and Significant Plants (ordered in terms of ecological importance and size/amount)	Nearly 3,200 ha of the Green Bay Open Water East priority area is **Green Bay open water** with little to no plant life, except for a few small stretches of **submergent marsh**[2,9]. Behind Renard Island is a submergent marsh that is dominated by sago pondweed (*Stuckenia pectinata*) and coontail (*Ceratophyllum demersum*)[9]; great duckweed (*Spirodela polyrrhiza*) and common waterweed (*Elodea canadensis*) also occur infrequently here[9]. An even smaller submergent marsh across from Scottwood Drive on the east shore is dominated by sago pondweed with a small amount of invasive Eurasian water-milfoil (*Myriophyllum spicatum*)[9]. The open water zone of this priority habitat often experiences harmful algal blooms in the late summer and early fall[7]. There is also nearly 6 ha of **Great Lakes beach** habitat, which is significant since it is a habitat that is both rare within the LGB&FR AOC and across the state[2,10]. Along the Bay Beach Amusement Park Shoreline (behind Renard Island) is highly modified Great Lakes beach that consists of large rock, small cobble, or sand and is mostly vegetated by common reed (*Phragmites australis*; hereafter referred to as *Phragmites*)[2,10]. Narrow stretches of Great Lakes beach extends from the Bay Beach Amusement Park Shoreline and private housing to the UW-Green Bay campus[2,10]. Campus Great Lakes beach consists of sand, shells (including zebra mussel [*Dreissena polymorpha*] shells), and rock (in some cases rip-rap) and is partially vegetated with cottonwood, sandbar

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[5] Klump et al. 1997: Sedimentary phosphorus cycling and a phosphorus mass balance for the Green Bay, Lake Michigan ecosystem

[6] Wisconsin's Historical Markers: http://www.wisconsinhistoricalmarkers.com/2012/09/grassy-island-range-lights.html

[7] Qualls et al. 2013: State of the Bay 2013: http://www.seagrant.wisc.edu/Home/Topics/HabitatsandEcosystems/Details.aspx?PostID=1840

[8] Epstein et al. 2002: "A data compilation and assessment of coastal wetlands of Wisconsin's Great Lakes"

[9] LGB&FR AOC Submerged Aquatic Vegetation Mapping; led by Dr. Amy Wolf and Dr. James Horn

[10] LGB&FR AOC Plant Biodiversity Hotspot Field Effort led by Dr. Amy Wolf, Dr. Robert Howe, and Dr. James Horn

	willow (*Salix interior*), box elder, green ash, gray dogwood (*Cornus foemina*), and common cocklebur (*Xanthium strumarium*)[2,10]. Invasives present along the beach include *Phragmites*, glossy buckthorn, dame's rocket (*Hesperis matronalis*), and others[2,10]. Rather thin stretches of Great Lakes beach line the eastern shore up until Point au Sable, which has a significant amount of Great Lakes beach around its perimeter. Point Sable's beaches primarily consist of zebra and quagga mussel shells with some sand and matted dead *Phragmites* stems[2,10]. However, several important native plants inhabit these shorelines, such as cocklebur, American red raspberry (*Rubus idaeus* subsp. *strigosus*), beach rocket (*Cakile edentula* var. *lacustris*), a state special concern species, and late goldenrod (*Solidago gigantea*)[2,10].
Significant Animals	**Birds**: • >100 bird species have been reported 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[11]: o Ducks, waterfowl, and waterbirds, including, but not limited to: ▪ Congregate in large groups during migration in the Green Bay Open Water East priority area (based on recent 2016-2017 LGB&FR AOC Migratory Waterfowl Study; surveys done by Tom Prestby): • Bonaparte's Gull (*Chroicocephalus philadelphia*) • Common Goldeneye (*Bucephala clangula*), state special concern species • Greater Scaup (*Aythya marila*) • Lesser Scaup (*Aythya affinis*), state special concern species, listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern, and regional priority species from the North American Waterfowl Management Plan • Red-breasted Merganser (*Mergus serrator*) • Ruddy Duck (*Oxyura jamaicensis*), state special concern species ▪ Other migratory waterfowl species include: • Bufflehead (*Bucephala albeola*) • Canada Goose (*Branta canadensis*), regional priority species from the North American Waterfowl Management Plan • Common Loon (*Gavia immer*) • Forster's Tern (*Sterna forsteri*), state endangered and listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern • Herring Gull (*Larus smithsonianus*) • Horned Grebe (*Podiceps auritus*), state special concern species and listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern • Ring-billed Gull (*Larus delawarensis*) o Herons/egrets, including, but not limited to: ▪ Great Egret (*Ardea alba*), state threatened and listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern ▪ Great Blue Heron (*Ardea herodias*) o Shorebirds, including, but not limited to: ▪ Spotted Sandpiper (*Actitis macularius*) ▪ Wilson's Phalarope (*Phalaropus tricolor*), state special concern species, listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern, and listed on the regional/continental

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[11] LGB&FR AOC Biota Database: file "AOCBiota_DB_ShareableVersion_20171213.accdb"

        priorities from the Upper Mississippi/Great Lakes Joint Venture Shorebird Plan
    - Raptors, including, but not limited to:
        - Bald Eagle (*Haliaeetus leucocephalus*), state special concern species and listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern
        - Osprey (*Pandion haliaetus*), listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern
    - During the breeding season and migration, swallows use nearshore habitats and open water for foraging
    - Great Egrets, Herring Gulls, and Double-crested Cormorants currently nest on Lone Tree Island[12]

Fish:

- >80 fish species have been recorded in the pelagic zone of the lower bay, including[11]:
    - 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): redside 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*)
    - Muskellunge (*Esox masquinongy*)
    - Northern pike (*Esox lucius*)
    - Pumpkinseed (*Lepomis gibbosus*)
    - Shortnose gar (*Lepisosteus platostomus*)
    - Smallmouth bass (*Micropterus dolomieu*)
    - Yellow perch (*Perca flavescens*)

Mammals:

- Although ~50 mammal species are known to or are expected to occur along the west shore (as noted in Roznik 1979)[13], only a small few likely use parts of the Green Bay Open Water East, including muskrat (*Ondatra zibethicus*), North American river otter (*Lontra canadensis*), and American mink (*Neovison vison*)[14,15]
- Bats also use nearshore airspace for foraging[16]

Mollusks:

- Within the pelagic zone of the lower bay, the following has been recorded[11]:
    - Freshwater clams: fingernail claim (*Sphaerium* sp.), pea clam (*Pisidium* sp.).

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[12] Personal communication with Thomas Prestby

[13] Green Bay West Shores Master Plan Concept Element 1979 by Roznik et al.

[14] Wisconsin Department of Natural Resources Technical Report PUB-LF-073.

[15] Wisconsin Department of Natural Resources 2015 muskrat house survey

[16] Jeremiah Shrovnal’s LGB&FR AOC Bat Study 2016

	o Three snails: mud bithynia (*Bithynia tentaculata*), river snail species (*Campeloma* sp.), and valve species (*Valvata* sp.) **Arthropods**: • Several species have been recorded in the pelagic zone of the lower bay in the 1990s, including: o Long-horn caddisfly (*Oecetis* sp.)[11] o Buzzer midge (*Chironomus plumosus*)[11] o Green midge (*Tanytarsus* sp.)[11] o Riffle beetle species (*Ordobrevia* sp.) from 2007[11] **Annelids**: • Aquatic oligochaete worms have been recorded in the pelagic zone of the lower bay in the early 1990s, including[11]: o *Aulodrilus americanus* o *Dero digitata* o *Nais pardalis* o *Potamothrix moldaviensis* o *Nais communis*
Habitat Quality	Overall, the ecological quality of the entire lower bay of Green Bay is relatively poor. The LGB&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. 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 their 2013 "State of the Bay" report[7]. 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)[7]**.** Nitrates received a "fair-good" rating with a deteriorating trend. Ammonia earned a "good" rating with an unchanging trend[7]. The lower bay also experiences summer and late fall blooms of harmful algae[7]. Between 1986 and 2013, NEW Water reported that the LGB&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[17].
Significant Invasive Species Issues	**Invasive Plant Species**: Each of these species outcompetes and crowds out native plants[2,9,10]: • Eurasian water-milfoil (*Myriophyllum spicatum*) o Found within some of the submergent marsh • Common reed (*Phragmites australis*) o Occurs along Great Lakes beach habitat along the Bay Beach Amusement Park and Bay Shore Woods and Beach (i.e., UW-Green Bay campus shoreline) • Glossy buckthorn (*Frangula alnus*) o Occurs along segments of the UW-Green Bay campus Great Lakes beach • Dame's rocket (*Hesperis matronalis*) o Occurs along segments of the UW-Green Bay campus Great Lakes beach

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[17] 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

	Invasive Animal Species: • *Fish*[11] o Alewife (*Alosa pseudoharengus*)[18] ▪ Poses a threat to native fish species by consuming zooplankton and disturbing the natural food web; not currently being managed o Common carp (*Cyprinus carpio*)[19] ▪ Destroy vegetation by uprooting plants and increasing cloudiness of water; not currently being managed o Rainbow smelt (*Osmerus mordax*)[20] ▪ Negatively affect uncommon to rare native fish species; not currently being managed o Round goby (*Neogobius melanostomus*)[21] ▪ Prey on small native fish and eggs (e.g., darters) and outcompete similarly sized native fish; not currently being managed o White perch (*Morone americana*)[22] ▪ Prey on native fish eggs, such as walleye; not currently being managed • *Freshwater mussels* o Zebra mussel (*Dreissena polymorpha*)[23] ▪ Poses threat to native freshwater mussels; not currently being managed
Management and Restoration Recommendations	• Control introduced plant species (e.g., Eurasian watermilfoil) and maintain extensive and high quality submerged aquatic vegetation with native plants. • 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 and around Renard Island. • Control woody successional and invasive plant species, remove accumulated zebra/quagga mussel shells, and restore native vegetation at undeveloped east shore beaches (e.g., Point au Sable, UW-Green Bay campus, Joliet Park, Bay Beach region). • Conduct biotic inventories along AOC shoreline and if necessary re-establish populations of native turtle species and other beach specialists. • Continue efforts to re-introduce *Hexagenia* (mayfly). • 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. • Identify critical buffer habitats and shorelines with potential den sites for mink, otter, and other shoreline wildlife species. • Implement Upper Fox, Wolf, and Lower Fox basin's total maximum daily loads (TMDL) to improve water quality.

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[18] 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

[19] 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

[20] 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

[21] 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

[22] 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

[23] Wisconsin Department of Natural Resources Technical Report PUBL ER-818 2010

	• Promote best management practices and innovative nutrient management measures in Fox River watershed. • Reduce unimpeded flow of toxins, nutrients, and sediments from urban/suburban storm water discharge pipes. • Implement effective non-point source pollution management plans in smaller watersheds and drainages. • Designate sensitive coastal landscapes at UW-Green Bay's Bay Shore Woods and Beach and Point Sable.
Reference Links and Documents	**Web Links**: • Fox 11 video on Green Bay poor water quality (including interview with Dr. Val Klump): ○ http://fox11online.com/news/fox-11-investigates/fox-11-investigates-poor-water-quality-plaguing-green-bay • NEW Water's Aquatic Monitoring Program: http://newwater.us/programs-initiatives/aquatic-monitoring-program/ • WDNR's Surface Water Data Viewer: https://dnrgis.wi.gov/H5/?Viewer=SWDV • NOAA's Lake Level Viewer: https://coast.noaa.gov/digitalcoast/tools/llv.html • TMDL and Watershed Management Plan for Total Phosphorus and Total Suspended Solids in the Lower Fox River Basin and Lower Green Bay: http://www.uwgb.edu/watershed/REPORTS/Related_reports/TMDLs/LFR_TMDL_EPA_Submittal_Aug_2011.PDF • "Dead zones haunt Green Bay as manure fuels algae blooms" (article by the *Journal Sentinel*): http://archive.jsonline.com/news/wisconsin/dead-zones-haunt-green-bay-as-manure-fuels-algae-blooms-die-offs-b99344902z1-274684741.html/ • Lower Fox Demonstration Farms Network: implementing farming best management practices in the lower Fox River watershed: https://fyi.uwex.edu/foxdemofarms/about-us/where-we-work/ • 1845 Map of Green Bay, which shows the historic barrier islands: http://s3.amazonaws.com/labaye/data/1845%20Head%20Of%20Green%20Bay.pdf **Reference Documents**: • 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. ○ https://dc.uwm.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=2047&context=etd • 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. • Disterhaft, K. 2013. Changes in fish assemblages of Lake Michigan's Green Bay following the introduction of Dreissenid mussels and round goby (*Neogobius melanostomus*) during 1980-2010. Master's thesis from the University of Wisconsin-Green Bay. • 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. Journal of Great Lakes Research 41:1024-1036. • 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. • 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. Canadian Journal of Fisheries and Aquatic Sciences 54:10-26.

	- 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. - Wisconsin Department of Natural Resources. 2014. Green Bay Planning Group Master Plan. Technical Report PUB-LF-075.
Site History (e.g., original vegetation, past conservation projects)	In the early 1630s, Frenchman Jean Nicolet first arrived in lower Green Bay when it was primarily inhabited by Native American tribes[24]. Lower Green Bay consisted of large beds of wild rice (*Zizania* sp.) and wild celery (*Vallisneria americana*), extensive emergent marsh (*Schoenoplectus* sp., cattail), sedge meadows (*Calamagrostis canadensis*), shrub carr (e.g., *Cornus* spp., *Salix* spp.), swamps, and wet conifer forest (black spruce [*Picea mariana*], balsam fir [*Abies balsamea*])[25,26,27,28,29]. Between the late 1600s and 1800s, European fur trade, duck hunting, fishing, logging, shipping, and agriculture were important early industries in lower Green Bay[30,31,32]. In the early 1800s, there were a few small settlements and farms of Europeans and Native Americans in the lower Bay[31]. Similar to the fur trade and logging, commercial fishing was an important industry in Green Bay, in which most fishermen primarily harvested whitefish, lake trout, and lake herring[7,33]. Other fish caught in Brown County in 1888 included perch, pike pickerel, suckers, catfish, muskellunge, and many others[7,34]. Unfortunately, significant anthropogenic changes, such as water pollution caused by the paper industry, led to the decline of many fish species as well as widespread overfishing[7,33]. 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[37]. Grassy Island had a small forest of cottonwood (*Populus deltoides*) and willow (*Salix* sp.) as well as a bulrush/sedge (*Scirpus-Eleocharis*) marsh[35]. Lone Tree Island was the only other island east of the present day shipping channel. In low water years, a cattail marsh formed in between Lone Tree Island and Grassy Island[36]. 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[27,37,41]. In low water years, Native Americans used to walk on foot from Point Sable to the west shore[41]. It was so shallow in fact that willows and cottonwoods grew on Frying Pan Shoal[41].

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

[25] Arthur C. Neville's Map of Historic Sites on Green Bay, Wisconsin 1669-1689. Available: http://s3.amazonaws.com/labaye/data/Bay%20Settle ment%20Map%20WI%20Historical%20Bulletin%201926.pdf (accessed on 24 Oct 2016)

[26] 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)

[27] 1845 Chart of Green Bay. Available http://s3.amazonaws.com/labaye/data/1845%20Chart%20of%20Green%20Bay.pdf (accessed on 24 Oct 2016)

[28] 1820s Fox River Military Road Map to Ft. Crawford. Available: http://s3.amazonaws.com/labaye/data/1820s%20Fox%20River%20Military%20 Road%20Map%20to%20Ft.%20Crawford.pdf (accessed on 24 Oct 2016)

[29] Personal communication with Thomas Erdman

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

[31] 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)

[32] 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)

[33] Qualls et al. (2013) cited Kraft, C. 1982. Green Bay's Yellow Perch Fishery. Wisconsin Sea Grant Publication. WIS. SG.82-725

[34] 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.

[35] Howlett 1974: The rooted vegetation of west Green Bay with reference to environmental change

[36] Herdendorf et al. 1981: Fish and Wildlife Resources of the Great Lakes Coastal Wetlands within the United States Vol 5: Lake Michigan, Part 3

[37] NOAA Navigational Chart: http://www.charts.noaa.gov/BookletChart/14910_BookletChart.pdf

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[38]. 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 traversed through Grassy Island and in between Longtail Point and the western edge of Point Sable Bar/Frying Pan Shoal[38,39]. Construction began in May the following year and was quickly finished by September 1867[38]. 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)[38]. By the early 1930s, the channel was widened again and increased depth to 6.71 m (22 ft)[38]. 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[40]. A break wall was constructed on the western edge of Lone Tree Island, which makes up the shipping channel's eastern edge and is visible on Brown County's 1938 air photo, with a house[41].

In June 1969, UW-Green Bay's Thomas Erdman and WDNR's Harold Mathiak conducted breeding bird censuses in the islands of the lower bay[41]. They found Black-crowned Night-Heron (*Nycticorax nycticorax*), Mallard (*Anas platyrhynchos*), Canada Goose, and Herring Gull nesting on Grassy Island[41]. The neighboring island, Lone Tree, which still exists today, provided nesting habitat for Common Tern (*Sterna hirundo*), Ring-billed Gull, and Spotted Sandpiper[41]. During extremely high lake levels and a series of damaging storms in the 1970s, nearly all of these barrier islands washed away. Grassy Island largely washed away though some of it still survived and provided nesting habitat for Double-crested Cormorant (*Phalacrocorax auritus*) and Black Tern (*Chlidonias niger*) in the 1970s[42]. Today, Grassy Island is gone, and it is unknown whether any underwater fish habitat is available from the remains of this island.

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[43,44]. 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[43]. A causeway was later built that connects the mainland to Renard Island on the island's westernmost section for convenient access and that has two culverts under the causeway[46]. Both the island and causeway changed the shoreline overtime, in which Great Lakes beach and emergent marsh expanded behind Renard Island, though they are now invaded by *Phragmties*. The causeway and Renard Island also altered sediment transport (per UW-Sea Grant's Julia Noordyk)[46].

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[38] *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

[39] U.S. Army Corps of Engineers Map of the shipping channel from 1898 and 1898; provided by Tom Erdman

[40] Wisconsin's Historical Markers: http://www.wisconsinhistoricalmarkers.com/2012/09/grassy-island-range-lights.html

[41] Personal communication with Thomas Erdman

[42] Bertrand et al. 1976: The Green Bay Watershed: Past/Present/Future

[43] U.S. Army Corps of Engineers 2011: Available: http://www.lre.usace.army.mil/Portals/69/docs/PPPM/PlanningandStudies/GBDMMP/ GreenBayDMMP2.pdf.

[44] U.S. Army Corps of Engineers map from 1966

While Renard Island is capped and covered by some short vegetation, it has provided poor quality terrestrial habitat[41]. Tom Erdman witnessed a botulism outbreak on Renard Island, which slowly killed infected waterbirds. Renard Island has also leached PCBs and caused high mortality to nesting birds[41]. Unfortunately, because the perimeter is built out of large rock, chicks have also fallen and become trapped in between the cracks in the rock during the breeding bird season[41]. That being said, the waters surrounding Renard Island are regularly used by many fish species. In fact, there is a spawning reef for walleye as well as woody debris for fish habitat[45]. Further improvements of fish habitat could be made around the waters of Renard Island, though very minimal terrestrial improvements are recommended.

Over the past several decades, the entire bay of Green Bay has been heavily studied by scientists from agencies, non-profit organizations, universities, and other organizations. The amount of knowledge accrued is truly significant. Below is a selected listing 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[48].
- WDNR’s Steven Hogler has conducted fyke net fish sampling along the east shore and fall electroshocking for young-of-year walleye and other species[46].
- In 2012, Steve Hogler also led a fish habitat restoration project around the waters of Renard Island by placing woody debris and building a spawning reef[47].
- 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[48].
- 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[48]. They plan to estimate the coastal wetland habitat that is used by sport fish species and to build habitat food webs[48]. They are also looking at spatial and temporal distributions of larval fish in the upper and lower bay[48].
- The U.S. Fish and Wildlife Service (FWS) coordinates an early detection and monitoring program of aquatic invasive species in Lake Michigan, and many of their sampling locations are in the LGB&FR AOC, including sites in Green Bay Open Water East[48]. They survey for ichthyoplankton, carp, macroinvertebrates, and nearshore fishes[48].
- FWS’ Steve Choy conducted sampling for smallmouth bass around Renard Island in 2012.
- NEW Water leads a long-term aquatic monitoring program with multiple sampling locations within the LGB&FR AOC as well as other parts of the bay of Green Bay and Fox River. They collect data on water temperature, dissolved oxygen, pH, phosphorus, nitrogen, turbidity, total suspended solids, and many others[49].
- Aquatic invertebrate data were collected in the bay of Green Bay in 1978, 1988, and 1994 with three sampling locations in Green Bay Open Water East (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 Porject 5073 Members and the Wisconsin Department of Natural Resources-Lake Michigan District. Appleton, Wisconsin: Integrated Paper Services, Inc.).
- In 2014-2016, UW-Milwaukee’s Dr. Jerry Kaster and graduate student Christopher Groff released 120 million eggs of *Hexagenia* (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.

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[45] Personal communication with WDNR’s Steve Hogler
[46] LGB&FR AOC Stakeholder Meeting on 23 June 2015
[47] AOC Conservation Project Catalogue
[48] Green Bay Fish Working Group Annual Meetings on 20 March 2015, 6 January 2016, and 4 January 2017
[49] NEW Water Aquatic Monitoring Program: http://newwater.us/programs-initiatives/aquatic-monitoring-program/

- 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&FR AOC[9].
- 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.
- In 2016-2017, under the guidance of CCB's Dr. Howe, Dr. Wolf, and Erin Giese, Tom Prestby surveyed migratory waterfowl within the LGB&FR AOC and mapped rafts.
- In the 1990s, UW-Green Bay's Thomas Erdman conducted nesting surveys at Renard Island on Common Tern, Forster's Tern (*Sterna forsteri*), Ring-billed Gull (*Larus delawarensis*), Black-crowned Night-Heron, and Herring Gull.
- 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[50].
- Surface Water Integrated Monitoring System (SWIMS): holds chemistry (water, sediment, fish tissue), physical, and biological (macroinvertebrate, aquatic invasives) data: http://dnr.wi.gov/topic/surfacewater/swims/
- Dr. Val Klump has spent a significant part of his career studying Green Bay water quality issues.
    - http://waterbase.uwm.edu/docs/Klump_Fermanich_2017_FinalReport_NA10NOS4780139_26Jan2017.pdf
- 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 lower bay[51].
- 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[47].
- Green Bay Ecosystem Modeling, UW-Extension's Chad Cook[47].
- Management Analysis Tool, which looks at how climate and landscape conservation can impact Green Bay water quality (Dr. Kevin Fermanich)[47].

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&FR AOC. Water quality, which affects wildlife species differently, 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 experience) harmful algal blooms, fish kills, and avian botulism[7,52,53,54]. However, despite poor water quality, other structural improvements, restoration efforts, and in some cases monitoring and species re-introductions are needed in the bay. Restoration of shoreline fish spawning and nursery habitats, such as rocky reefs, gravel, cobble, woody debris, and sandy areas, are needed. Reintroductions of freshwater mussels and possibly native turtle species will also be needed. Improvements to shoreline habitat and den sites for mink and otter could furthermore be made. Efforts should continue to be made to re-introduce *Hexagenia* in the bay, one of several bottom of the food chain-species. To improve water quality, implementing best management practices for agriculture and TMDLs for the Upper Fox, Wolf, and Lower Fox basins will be necessary.

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.

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[50] Personal communication with WDNR's Steve Hogler

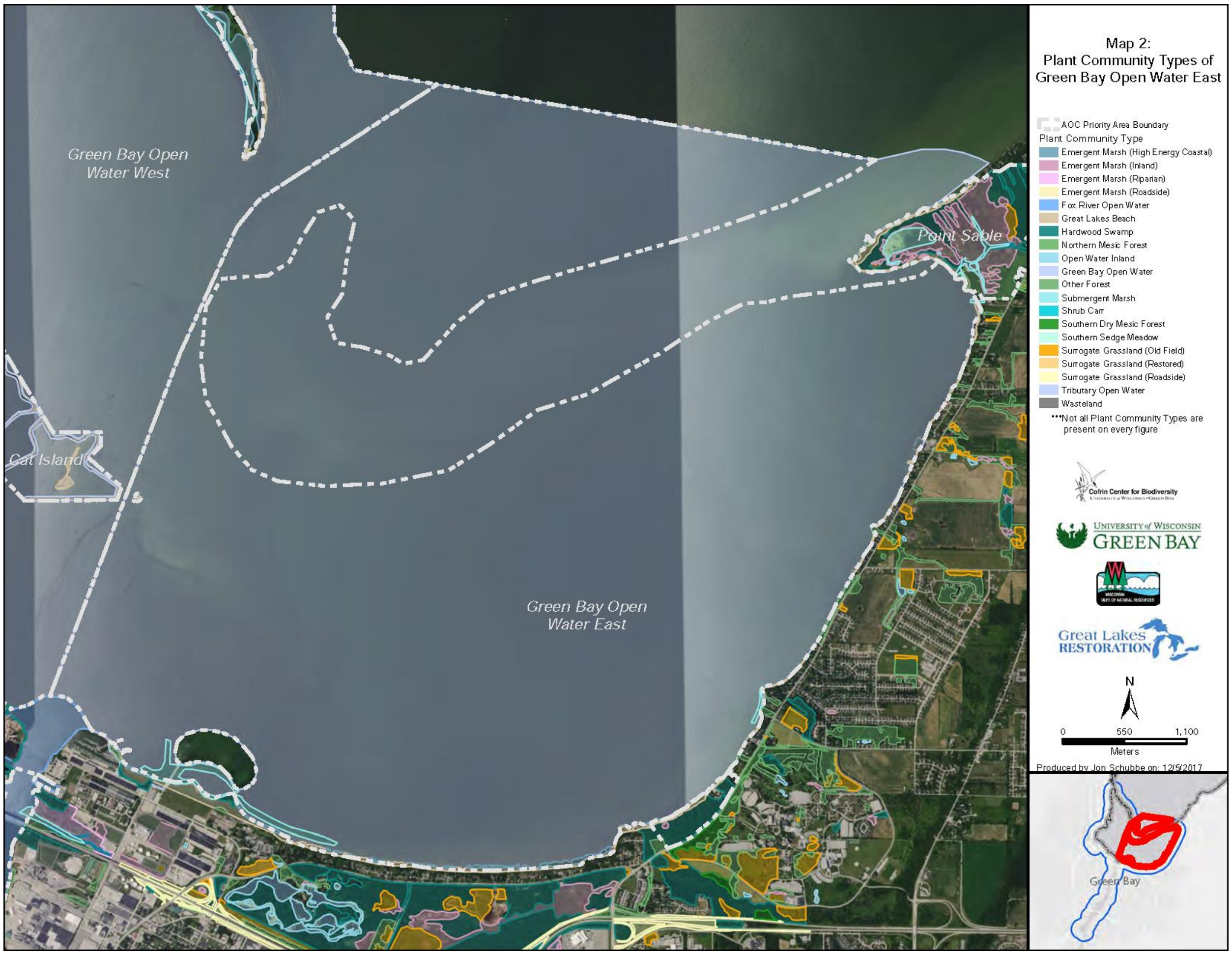
[51] Lower Fox Demonstration Farms Network: https://fyi.uwex.edu/foxdemofarms/about-us/where-we-work/

[52] Silliman et al. 2001: "A hypothesis for the origin of perylene based on its low abundance in sediments of Green Bay, Wisconsin"

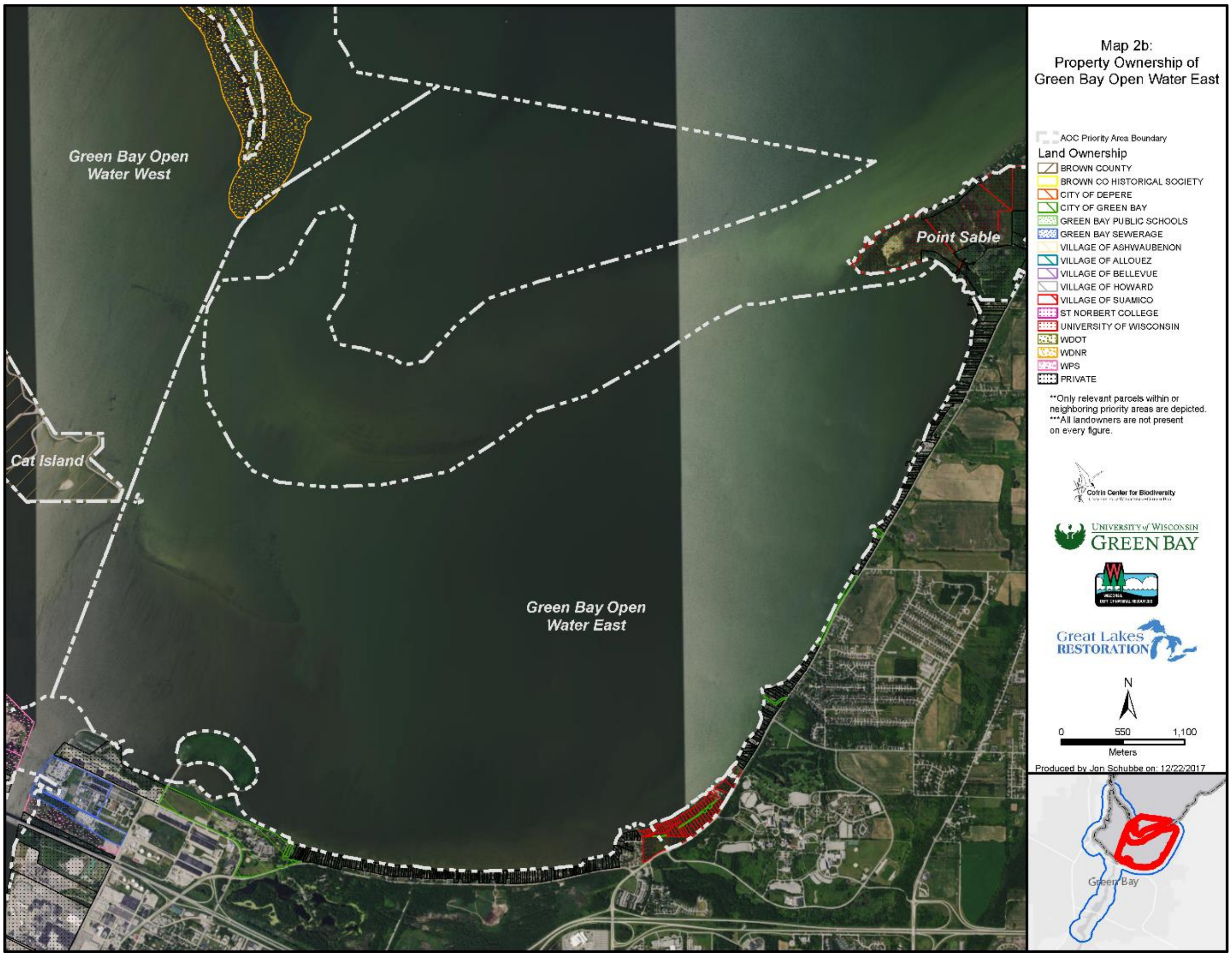
[53] Smith et al. 1988: "Estuary Rehabilitation: The Green Bay Story"

[54] Brand et al. 1983: Waterbird mortality from botulism type E in Lake Michigan: an update"

Map of Green Bay Open Water East 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 East. Map made by UW-Green Bay's Jon Schubbe.



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

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

Appendix 10.3: Green Bay Open Water West

Written by Erin Giese and James Horn

<table>
<tr><td>Location (centroid)</td><td>Lat. 44.583458°, Lon. -88.002331°[1] (NAD 1983, UTM Zone 16N)</td></tr>
<tr><td>Total Area (ha)</td><td>2,165.46 ha</td></tr>
<tr><td>Area Public Land (ha)</td><td>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.</td></tr>
<tr><td>Area of Habitat Types Present (ha) and Percent of Each Habitat Type</td><td>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&FR AOC)[2]. 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.
<table>
<tr><th>Habitat Type</th><th>Area (ha)</th><th>Percent</th></tr>
<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>
</table>
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.</i></td></tr>
<tr><td>General Description</td><td>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[3]. 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[3]. 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[4]. Sediments largely consist of sand and silt[38]. Unfortunately, water quality in the lower bay has been poor</td></tr>
</table>

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[1] File “AOC_PriorityAreas.v09_20171212.shp”

[2] LGB&FR AOC 2015 habitat field mapping effort

[3] 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

[4] Klump et al. 1997: Sedimentary phosphorus cycling and a phosphorus mass balance for the Green Bay, Lake Michigan ecosystem

	for decades. The LGB&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&FR AOC regularly report high concentrations of total phosphorus, total suspended solids, nitrates/nitrates, and toxic chemicals, leading to poor overall water quality[5,46]. It can also be turbid and experience summer and late fall blooms of harmful algae[5]. 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&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.
Special Features	• Provides critical open water and nearshore fish habitat. • Provides habitat for open water and nearshore aquatic invertebrates, including freshwater mussels, aquatic insects, arthropods, annelids, etc. • Contains Great Lakes beach, which is rare to both the state of WI and the LGB&FR AOC, and nearshore and submergent marsh habitats. • Important waterfowl migratory bird stopover site, particularly along the west shore, Cat Island Wave Barrier, Duck Creek Delta, and Longtail Point[6]. • During relatively high lake levels, narrow stretches of submergent marshes line the entire border with terrestrial habitats of the west shore. • 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.
Natural Habitat Communities and Significant Plants (ordered in terms of ecological importance and size/amount)	Nearly 2,100 ha of the Green Bay Open Water West priority area is **Green Bay open water** with little to no plant life, with the exception of long stretches of **submergent marsh** that line nearly all of the terrestrial borders of this priority area and make up 51.6 ha[2,7]. The submergent marshes between the mouth of the Fox River and Duck Creek Delta are dominated by coontail (*Ceratophyllum demersum*), sago pondweed (*Stuckenia pectinata*), and Eurasian water-milfoild, (*Myriophyllum spicatum*)[7]. Leafy pondweed (*Potamogeton foliosus*) is moderately common behind the westernmost portion of the Cat Island Wave Barrier[7]. Along the southern edge of Peters Marsh are coontail, perennial duckweed (*Lemna turionifera*), giant pondweed, and leafy pondweed[7]. Dominants along the Malchow/Olson Tract submergent marsh include sago pondweed, Eurasian-watermilfoil, coontail, and common bladderwort (*Utricularia vulgaris*), while Dead Horse Bay has wild celery, bladderwort, coontail, and many others[7]. The open water zone of this priority area often experiences harmful algal blooms in the late summer and early fall[5]. There is also 4.52 ha ha of **Great Lakes beach** habitat, which is significant since it is a habitat that is both rare within the LGB&FR AOC and across the state[2,8]. 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

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

[6] Epstein et al. 2002

[7] LGB&FR AOC Submerged Aquatic Vegetation Mapping; led by Dr. Amy Wolf and Dr. James Horn

[8] LGB&FR AOC Plant Biodiversity Hotspot Field Effort led by Dr. Amy Wolf, Dr. Robert Howe, and Dr. James Horn

	common reed (*Phragmites australis*; hereafter referred to as *Phragmites*)[2]. Native plants that inhabit these shorelines include beach rocket (*Cakile edentula var. lacustris*), a state special concern species, and cottonwood[8].
Significant Animals	**Birds**: • >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[9]: o Ducks, waterfowl, and waterbirds, including, but not limited to: ▪ Congregate in large groups during migration in the Green Bay Open Water West priority area (based on recent 2016-2017 LGB&FR AOC Migratory Waterfowl Study; surveys done by Tom Prestby): • Common Merganser (*Mergus merganser*) • Mallard (*Anas platyrhynchos*), regional priority species from the North American Waterfowl Management Plan • Scaup (Greater, *Aythya marila* or Lesser, *Aythya affinis*) • Herring Gull (*Larus smithsonianus*) • Ring-billed Gull (*Larus delawarensis*) • American Coot (*Fulica americana*) • Bonaparte’s Gull (*Chroicocephalus philadelphia*) • Double-crested Cormorant (*Phalacrocorax auritus*) • Red-breasted Merganser (*Mergus serrator*) • Ruddy Duck (*Oxyura jamaicensis*), state special concern species • Canada Goose (*Branta canadensis*), regional priority species from the North American Waterfowl Management Plan ▪ Other migratory waterfowl species include: • Common Goldeneye (*Bucephala clangula*), a state special concern species • American Black Duck (*Anas rubripes*), 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 • Bufflehead (*Bucephala albeola*) • Pied-billed Grebe (*Podilymbus podiceps*), listed on the Upper Mississippi River/Great Lakes Waterbird Conservation Plan • Green-winged Teal (*Anas carolinensis*) • Common Loon (*Gavia immer*) • Horned Grebe (*Podiceps auritus*), state special concern species and listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern • Tundra Swan (*Cygnus columbianus*), regional priority species from the North American Waterfowl Management Plan o Herons/egrets, including, but not limited to: ▪ Great Egret (*Ardea alba*), state threatened and listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern ▪ Great Blue Heron (*Ardea herodias*)

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[9] 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[10]
    - 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[10]
    - Annually between 2015 and 2017, Common Terns (*Sterna hirundo*) successfully nested on artificial nesting platforms built and monitored by the WDNR and FWS[10]
        - 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[10]
    - >30 shorebird species use the open mud flats and edges of the causeway for foraging and stopover habitat[11]

Fish:

- >80 fish species have been recorded in the pelagic zone of the lower bay, including[9]:
    - 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): redside 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*)

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[10] Personal communication with Thomas Prestby

[11] Shorebird master’s project by UW-Green Bay graduate student, Thomas Prestby (2016)

	o Muskellunge (*Esox masquinongy*) o Northern pike (*Esox lucius*) o Pumpkinseed (*Lepomis gibbosus*) o Shortnose gar (*Lepisosteus platostomus*) o Smallmouth bass (*Micropterus dolomieu*) o Yellow perch (*Perca flavescens*) **Mammals**: • Although ~50 mammal species are known or are expected to occur along the west shore (as noted in Roznik 1979)[12], only a few likely use parts of the Green Bay Open Water West, including muskrat (*Ondatra zibethicus*), North American river otter (*Lontra canadensis*), and American mink (*Neovison vison*)[13,14] • Bats also use nearshore airspace for foraging[15] **Mollusks**: • Within the pelagic zone of the lower bay, the following has been recorded[9]: o Freshwater clams: fingernail claim (*Sphaerium* sp.), pea clam (*Pisidium* sp.) o Three snails: mud bithynia (*Bithynia tentaculata*), river snail species (*Campeloma* sp.), and valve species (*Valvata* sp.) **Arthropods**: • Several species have been recorded in the pelagic zone of the lower bay in the 1990s, including: o Long-horn caddisfly (*Oecetis* sp.)[9] o Buzzer midge (*Chironomus plumosus*)[9] o Green midge (*Tanytarsus* sp.)[9] o Riffle beetle species (*Ordobrevia* sp.) from 2007[9] **Annelids**: • Aquatic oligochaete worms have been recorded in the pelagic zone of the lower bay in the early 1990s, including[9]: o *Aulodrilus americanus* o *Dero digitata* o *Nais pardalis* o *Potamothrix moldaviensis* o *Nais communis*
Habitat Quality	Overall, the ecological quality of the entire lower bay of Green Bay is relatively poor. The LGB&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. 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[5]. 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)[5]. Nitrates received a “fair-good” rating with a deteriorating trend. Ammonia earned a “good” rating with an unchanging trend[5]. The lower bay also experiences summer and late fall blooms of harmful algae[5].

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[12] Green Bay West Shores Master Plan Concept Element 1979 by Roznik et al.
[13] Wisconsin Department of Natural Resources Technical Report PUB-LF-073
[14] Wisconsin Department of Natural Resources 2015 muskrat house survey
[15] Jeremiah Shrovnal’s LGB&FR AOC Bat Study 2016

	Between 1986 and 2013, NEW Water reported that the LGB&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[16]. 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.
Significant Invasive Species Issues	**Invasive Plant Species**: Each of these species outcompetes and crowds out native plants[2,7,8]: • Eurasian water-milfoil (*Myriophyllum spicatum*) o Found within some of the submergent marsh • Common reed (*Phragmites australis*) o Occurs along Great Lakes beach habitat along the northern shoreline of Longtail Point; some management has occurred in recent years **Invasive Animal Species**: • *Fish*[9] o Alewife (*Alosa pseudoharengus*)[17] ▪ Poses a threat to native fish species by consuming zooplankton and disturbing the natural food web; not currently being managed o Common carp (*Cyprinus carpio*)[18] ▪ Destroy vegetation by uprooting plants and increasing cloudiness of water; not currently being managed o Rainbow smelt (*Osmerus mordax*)[19] ▪ Negatively affect uncommon to rare native fish species; not currently being managed o Round goby (*Neogobius melanostomus*)[20] ▪ Prey on small native fish and eggs (e.g., darters) and outcompete similarly sized native fish; not currently being manage o White perch (*Morone americana*)[21] ▪ Prey on native fish eggs, such as walleye; not currently being managed • *Freshwater mussels* o Zebra mussel (*Dreissena polymorpha*)[22]

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[16] 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

[17] 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

[18] 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

[19] 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

[20] 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

[21] 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

[22] Wisconsin Department of Natural Resources Technical Report PUBL ER-818 2010: file "WDNR2010_RapidEcologicalAssmtForGBWestShores WildlifeArea.pdf"

	▪ Poses threat to native freshwater mussels; not currently being managed
Management and Restoration Recommendations	• Control introduced plant species (e.g., Eurasian watermilfoil) and maintain extensive and high quality submerged aquatic vegetation with native plants. • 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. • Continue efforts to re-introduce *Hexagenia* (mayfly). • 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. • Aggressively remove invasive species and restore low shorelines at river mouths of west shore tributaries. • Identify critical buffer habitats and shorelines with potential den sites for mink, otter, and other shoreline wildlife species. • Implement Upper Fox, Wolf, and Lower Fox basin's total maximum daily loads (TMDL) to improve water quality. • Promote best management practices and innovative nutrient management measures in Fox River watershed. • Reduce unimpeded flow of toxins, nutrients, and sediments from urban/suburban storm water discharge pipes. • Implement effective non-point source pollution management plans in smaller watersheds and drainages. • See the Cat Island priority area narrative for project recommendations that relate to the Cat Island Wave Barrier.
Reference Links and Documents	**Web Links**: • Fox 11 video on Green Bay poor water quality (including interview with Dr. Val Klump): ○ http://fox11online.com/news/fox-11-investigates/fox-11-investigates-poor-water-quality-plaguing-green-bay • NEW Water's Aquatic Monitoring Program: http://newwater.us/programs-initiatives/aquatic-monitoring-program/ • WDNR's Surface Water Data Viewer: https://dnrgis.wi.gov/H5/?Viewer=SWDV • NOAA's Lake Level Viewer: https://coast.noaa.gov/digitalcoast/tools/llv.html • TMDL and Watershed Management Plan for Total Phosphorus and Total Suspended Solids in the Lower Fox River Basin and Lower Green Bay: http://www.uwgb.edu/watershed/REPORTS/Related_reports/TMDLs/LFR_TMDL_EPA_Submittal_Aug_2011.PDF • "Dead zones haunt Green Bay as manure fuels algae blooms" (article by the *Journal Sentinel*): http://archive.jsonline.com/news/wisconsin/dead-zones-haunt-green-bay-as-manure-fuels-algae-blooms-die-offs-b99344902z1-274684741.html/ • Lower Fox Demonstration Farms Network: implementing farming best management practices in the lower Fox River watershed: https://fyi.uwex.edu/foxdemofarms/about-us/where-we-work/ • Nonpoint Source Control Plan for the Duck, Apple, and Ashwaubenon Creeks Priority Watershed Project: http://dnr.wi.gov/topic/nonpoint/documents/9kep/Duck_Apple_Ashwaubenon_Creeks-Plan.pdf • Wild rice seeding in the lower bay of Green Bay, led by Dr. Amy Carrozzino-Lyon: http://www.ducks.org/conservation/glar/wisconsin/green-bay-partnership-to-improve-wildlife-habit-water-quality • 1845 Map of Green Bay, which shows the historic barrier islands: http://s3.amazonaws.com/labaye/data/1845%20Head%20Of%20Green%20Bay.pdf

	Reference Documents: • 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. ○ https://dc.uwm.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=2047&context=etd • 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. • Disterhaft, K. 2013. Changes in fish assemblages of Lake Michigan's Green Bay following the introduction of Dreissenid mussels and round goby (*Neogobius melanostomus*) during 1980-2010. Master's thesis from the University of Wisconsin-Green Bay. • 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. Journal of Great Lakes Research 41:1024-1036. • 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. • 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. Canadian Journal of Fisheries and Aquatic Sciences 54:10-26. • 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. • Wisconsin Department of Natural Resources. 2014. Green Bay Planning Group Master Plan. Technical Report PUB-LF-075.
Site History (e.g., original vegetation, past conservation projects)	In the early 1630s, Frenchman Jean Nicolet first arrived in lower Green Bay when it was primarily inhabited by Native American tribes[23]. Lower Green Bay consisted of large beds of wild rice (*Zizania* sp.) and wild celery (*Vallisneria americana*), extensive emergent marsh (*Schoenoplectus* sp., cattail), sedge meadows (*Calamagrostis canadensis*), shrub carr (e.g., *Cornus* spp., *Salix* spp.), swamps, and wet conifer forest (black spruce [*Picea mariana*], balsam fir [*Abies balsamea*])[24,25,26,27,28]. Between the late 1600s and 1800s, European fur trade, duck hunting, fishing, logging, shipping, and agriculture were important early industries in lower Green Bay[29,30,31]. In the early 1800s, there were a few small settlements and farms of Europeans and Native Americans in the lower Bay[30]. Similar to the fur trade and logging, commercial fishing was an important industry in Green Bay, in which most fishermen primarily harvested

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

[24] Arthur C. Neville's Map of Historic Sites on Green Bay, Wisconsin 1669-1689. Available: http://s3.amazonaws.com/labaye/data/Bay%20Settle ment%20Map%20WI%20Historical%20Bulletin%201926.pdf (accessed on 24 Oct 2016)

[25] 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)

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

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

[28] Personal communication with Thomas Erdman

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

[30] 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)

[31] 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[5,32]. Other fish caught in Brown County in 1888 included perch, pike pickerel, suckers, catfish, muskellunge, and many others[5,33]. Unfortunately, overfishing and other significant anthropogenic changes, such as water pollution caused by the paper industry, led to the decline of many fish species[5,32].

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[35]. Grassy Island had a small forest of cottonwood (*Populus deltoides*) and willow (*Salix* sp.) as well as a bulrush/sedge (*Scirpus-Eleocharis*) marsh[34]. 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[26,35,39]. In low water years, Native Americans used to walk on foot from Point Sable to the west shore[39]. It was so shallow in fact that willows and cottonwoods used to grown on Frying Pan Shoal[39].

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[36]. 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[36,37]. Construction began in May the following year and was quickly finished by September 1867[36]. 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)[36]. By the early 1930s, the channel was widened again and increased depth to 6.71 m (22 ft)[36]. 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[38]. 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[39].

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[39]. In the 1970s, they switched to feeding in open fields[39]. 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[39]. 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[39]. Unlike the present day, Cat Island Proper used to have willows and cottonwoods growing in the mid-1960s, though eventually the guano

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

[33] 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

[34] Howlett 1974: The rooted vegetation of west Green Bay with reference to environmental change

[35] NOAA Navigational Chart: http://www.charts.noaa.gov/BookletChart/14910_BookletChart.pdf

[36] *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

[37] U.S. Army Corps of Engineers Map of the shipping channel from 1898 and 1898; provided by Thomas Erdman

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

[39] Personal communication with Thomas Erdman

of these nesting birds killed the trees[39]. 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[40,41]. 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[40]. 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)[42].

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[43,44]. 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[43,44]. 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[43]. It took decades for that idea to materialize and became a reality, but it finally happened[43]. 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[43,45]. 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[46].
- 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[46].

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[40] U.S. Army Corps of Engineers 2011: Available: http://www.lre.usace.army.mil/Portals/69/docs/PPPM/PlanningandStudies/GBDMMP/ GreenBayDMMP2.pdf

[41] U.S. Army Corps of Engineers map from 1966

[42] LGB&FR AOC Stakeholder Meeting on 23 June 2015

[43] Brown County Port and Resource Recovery Cat Island document: https://static1.squarespace.com/static/56ec0372859fd0e272858772/t/574db48fab48de7bc23597a0/1464710289702/2014+Cat+Island+Abstract+Spring.pdf

[44] Frieswyk and Zedler 2007: "Identifying and characterizing dominant plants as an indicator of community condition."

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

	• 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[46]. They plan to estimate the coastal wetland habitat that is used by sport fish species and to build habitat food webs[46]. They are also looking at spatial and temporal distributions of larval fish in the upper and lower bay[46]. • 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&FR AOC, including sites in Green Bay Open Water West[46]. They survey for ichthyoplankton, carp, macroinvertebrates, and nearshore fishes[46]. • NEW Water leads a long-term aquatic monitoring program with multiple sampling locations within the LGB&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[47]. • 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.) • In 2014-2016, UW-Milwaukee's Dr. Jerry Kaster and graduate student Christopher Groff released 120 million eggs of *Hexagenia* (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. • 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). • 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&FR AOC[7]. • 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[48]. • 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. • In 2016-2017, under the guidance of CCB's Dr. Howe, Dr. Wolf, and Erin Giese, Tom Prestby surveyed migratory waterfowl within the LGB&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. • Since 1997, the Oneida Tribe has conducted continuous water monitoring with USGS in Duck Creek[50]. • Surface Water Integrated Monitoring System (SWIMS): holds chemistry (water, sediment, fish tissue), physical, and biological (macroinvertebrate, aquatic invasives) data: http://dnr.wi.gov/topic/surfacewater/swims/ • Dr. Val Klump has spent a significant part of his career studying Green Bay water quality issues. ○ http://waterbase.uwm.edu/docs/Klump_Fermanich_2017_FinalReport_NA10NOS4780139_26Jan2017.pdf

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[46] Green Bay Fish Working Group Annual Meetings on 20 March 2015, 6 January 2016, and 4 January 2017

[47] NEW Water Aquatic Monitoring Program: http://newwater.us/programs-initiatives/aquatic-monitoring-program/

[48] Personal communication with WDNR's Steve Hogler

	• 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[49]. • 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.[50]. • Green Bay Ecosystem Modeling, UW-Extension's Chad Cook[50]. • Management Analysis Tool, which looks at how climate and landscape conservation can impact Green Bay water quality (Dr. Kevin Fermanich)[50]. 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&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[5,51,52,53]. 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 *Hexagenia* 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. 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.

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[49] Lower Fox Demonstration Farms Network: https://fyi.uwex.edu/foxdemofarms/about-us/where-we-work/

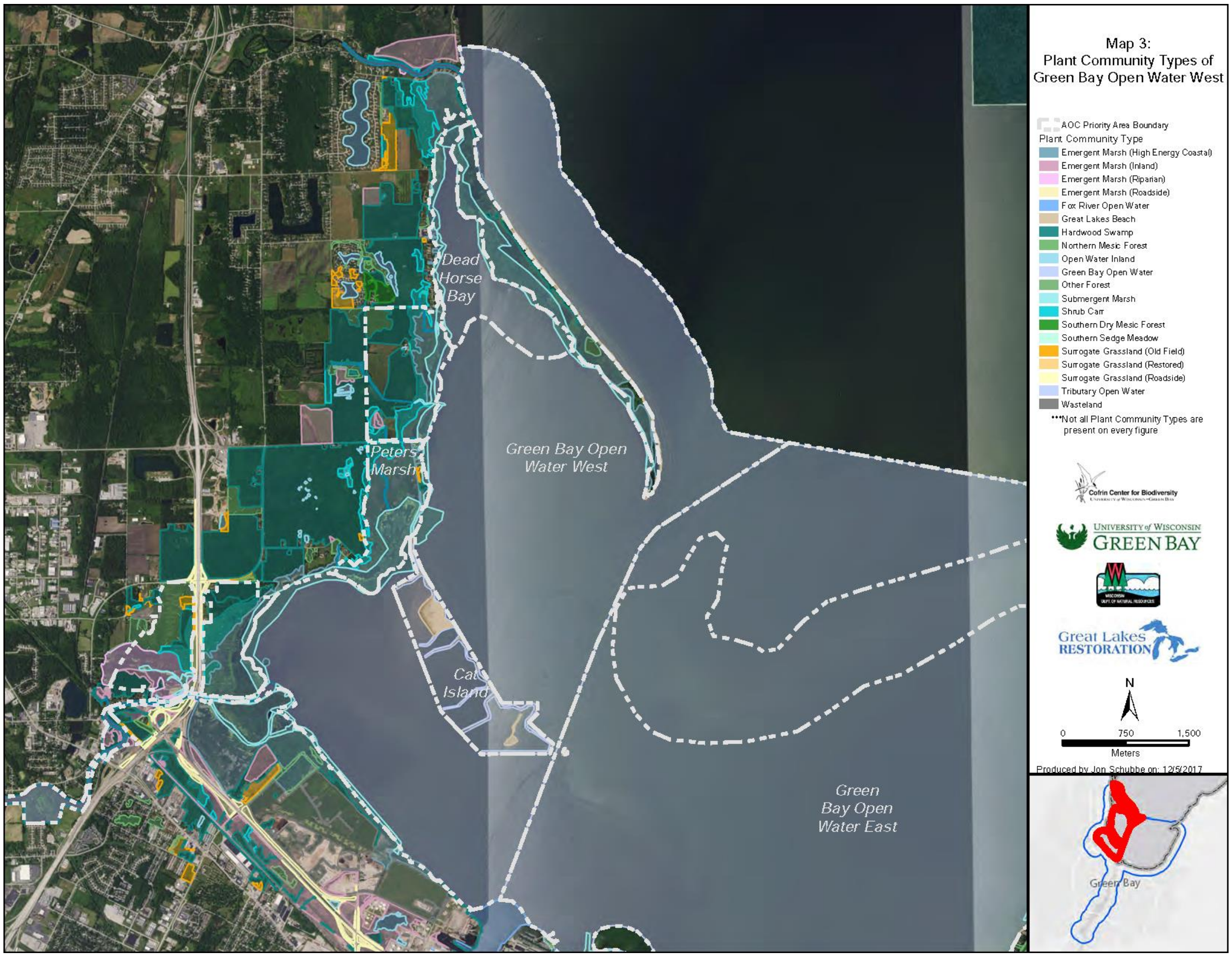
[50] AOC Conservation Project Catalogue

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

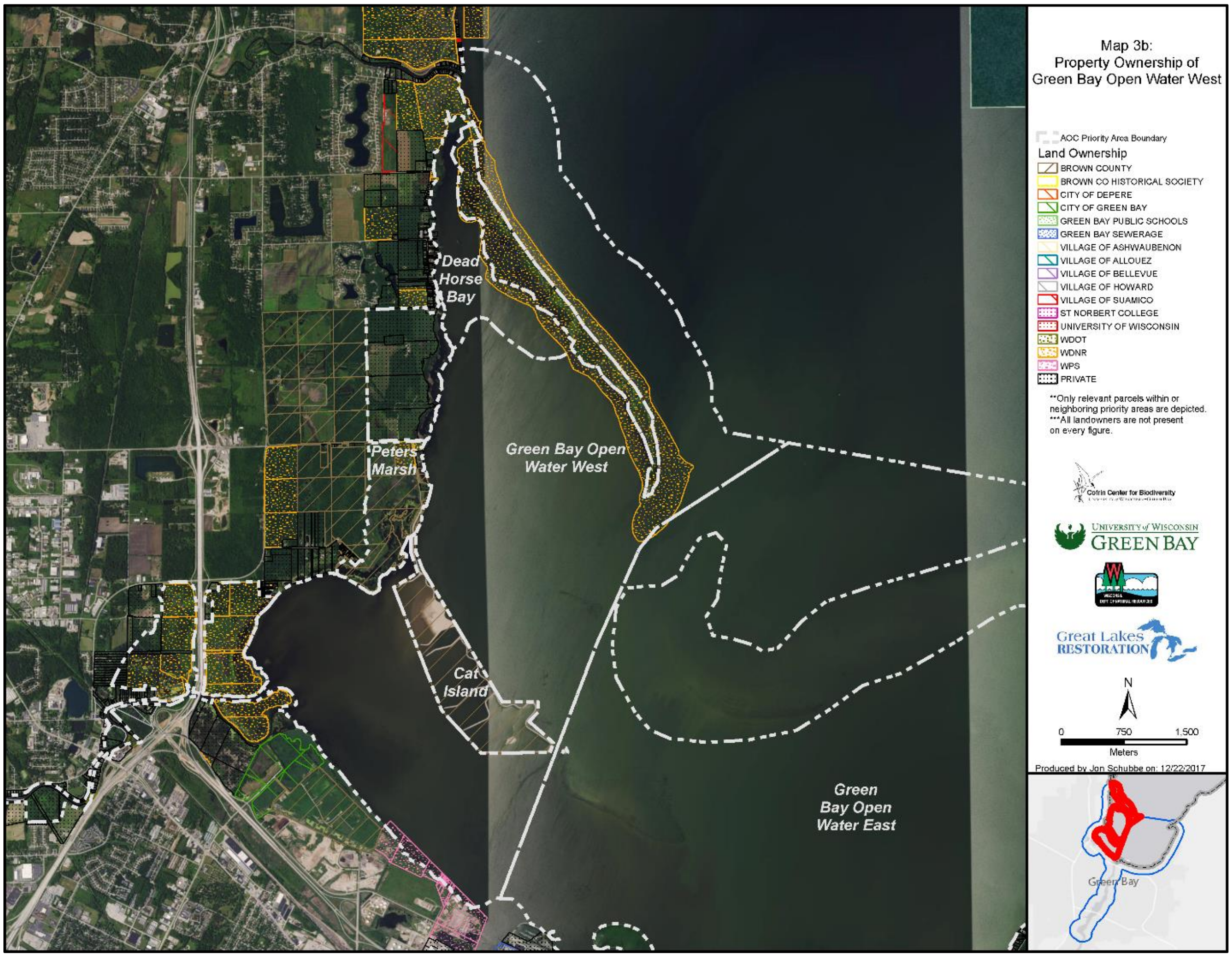
[52] Smith et al. 1988: "Estuary Rehabilitation: The Green Bay Story"

[53] 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.

Appendix 10.4: Bay Shore Woods and Beach

Written by Erin Giese and James Horn

<table>
<tr><td>Location (centroid)</td><td>Lat. 44.533670°, Lon. -87.931459°[1] (NAD 1983, UTM Zone 16N)</td></tr>
<tr><td>Total Area (ha)</td><td>18.56 ha</td></tr>
<tr><td>Area Public Land (ha)</td><td>16.02 ha</td></tr>
<tr><td>Area of Habitat Types Present (ha) and Percent of Each Habitat Type</td><td>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&FR AOC)[2]. Habitat types within Bay Shore Woods and Beach are displayed as a static map at the bottom of this document. There is a total of 16.41 ha of natural habitat within Bay Shore Woods and Beach.
<table>
<tr><th>Habitat Type</th><th>Area (ha)</th><th>Percent</th></tr>
<tr><td>Emergent Marsh (High Energy Coastal)</td><td>0.87</td><td>5.29</td></tr>
<tr><td>Emergent Marsh (Inland)</td><td>0.21</td><td>1.31</td></tr>
<tr><td>Great Lakes Beach</td><td>1.28</td><td>7.80</td></tr>
<tr><td>Hardwood Swamp</td><td>14.00</td><td>85.34</td></tr>
<tr><td>Other Forest</td><td>0.04</td><td>0.26</td></tr>
</table>
<i>Disclaimer! 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 extent of Great Lakes beach and emergent marsh (high energy coastal) habitats may 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 August and September of 2016. Great Lakes water levels were much higher in 2016 than in July 2015.</i></td></tr>
<tr><td>General Description</td><td>Bay Shore Woods and Beach is a priority area located within the western corner of the University of Wisconsin-Green Bay campus and is a part of the Cofrin Memorial Arboretum. The property is owned and managed by the UW-Green Bay Cofrin Center for Biodiversity (CCB), though the City of Green Bay owns two small parcels. It primarily follows the bay of Green Bay shoreline and almost entirely consists of hardwood swamp, though emergent high energy marsh and Great Lakes beach are found along the shoreline[2]. Great Lakes beach is a relatively rare habitat within the LGB&FR AOC as well as within the state of Wisconsin; nearly 0.7 km of beach traces the shoreline of this priority area[2]. The northeastern half of this priority area consists of Keowns silt loam soils, while the southwestern half is Allendale loamy fine sand along the shoreline and Poygan silty clay loam soils in the forested areas[3]. Although several invasive plant species frequent parts of the hardwood swamp and shoreline, it</td></tr>
</table>

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[1] File “AOC_PriorityAreas.v09_20171212.shp”.

[2] LGB&FR AOC 2015 habitat field mapping effort: http://uwgb.maps.arcgis.com/home/item.html?id=fdf942b9dd224094b0841a08437f95f0.

[3] Soil Survey Geographic (SSURGO) by the United States Department of Agriculture’s Natural Resources Conservation Service. Published Dec 2010. Available: http://uwgb.maps.arcgis.com/home/item.html?id=204d94c9b1374de9a21574c9efa31164; accessed 14 October 2016.

	still supports ~180 bird species annually (both migratory and breeding)[4,5,7,10,11,12], 18 known odonate (dragonflies and damselflies) species[17], >30 fish species offshore, and several mammal and reptile species[7]. Because UW-Green Bay owns this priority area, it is extremely well-studied by university and agency scientists, particularly for plants, birds, and some arthropods[6]. CCB staff have also been actively managing invasive plant species, especially understory woody plants (e.g., glossy buckthorn [*Frangula alnus*]), to try and improve these important wildlife habitats.
Special Features	• Largely dominated by hardwood swamp but also includes ~0.7 km of Great Lakes beach, a habitat that is rare to both the state of WI and LGB&FR AOC[2]. • Breeding and migratory stopover habitat for ~180 bird species[4,5,7,10,11,12]. • Provides habitat for odonates (dragonflies and damselflies) within Bay Shore Woods and Beach and neighboring parts of the Cofrin Memorial Arboretum[17]. • Forest habitat for >20 mammal species, including several furbearers[7].
Natural Habitat Communities and Significant Plants (ordered in terms of ecological importance and size/amount)	The majority of Bay Shore Woods and Beach consists of **hardwood swamp**, which has a canopy dominated by green ash (*Fraxinus pennsylvanica*), cottonwood (*Populus deltoides*), and box elder (*Acer negundo*)[2,8]. In the understory are grape woodvine (*Parthenocissus inserta*), ostrich fern (*Matteuccia struthiopteris*), white avens (*Geum canadense*), American black currant (*Ribes americanum*), and little false Solomon's-seal (*Maianthemum stellatum*)[2,8]. A very small area to the southwest of the northern parking lot contains a high-quality **southern mesic forest** community. The canopy here is dominated by American basswood (*Tilia americana*), and the herbaceous understory includes a diverse assemblage of spring ephemerals, including wild ginger (*Asarum canadense*), red baneberry (*Actaea rubra*), Jack-in-the-pulpit (*Arisaema triphyllum*), May-apple (*Podophyllum peltatum*), and bloodroot (*Sanguinaria canadensis*)[2,9]. This area is not delineated on the habitat map below because it is very small and was therefore not found or mapped during the 2015 LGB&FR AOC field effort. Along the shoreline of Bay Shore Woods and Beach are approximately 0.7 km of **Great Lakes beach** and **emergent high energy marsh**, both of which connect to these same two habitats located in the Mahon Woods and Creek priority area[2]. The beach consists of sand, shells (including zebra mussel [*Dreissena polymorpha*] shells), and rock (in some cases rip-rap) and is partially vegetated with cottonwood, sandbar willow (*Salix interior*), box elder, green ash, gray dogwood (*Cornus foemina*), and common cocklebur (*Xanthium strumarium*)[2,8]. Invasives present along the beach include common reed (*Phragmites australis*; hereafter referred to as *Phragmites*), glossy buckthorn, dame's rocket (*Hesperis matronalis*), and others[2,8]. The **emergent high energy marsh** is dominated by *Phragmites*, though several natives also occur here including bulrush (*Schoenoplectus* sp.), bulblet water-hemlock (*Cicuta bulbifera*), lesser duckweed (*Lemna minor*), and orange jewelweed (*Impatiens capensis*)[2,8]. In the southwestern corner of this priority area is a small **inland emergent marsh**, which was formerly a small pond that is now filled with a dense, clonal stand of *Phragmites*. There is also a moderate amount of small-spike false nettle (*Boehmeria cylindrica*)[8].

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[4] eBird 2016: http://ebird.org/ebird/hotspot/L159722 (as of 10 Nov 2016).

[5] Wisconsin Breeding Bird Atlas II Project (2015-2019): http://ebird.org/ebird/atlaswi/block/4408758SE?atlasPeriod=EBIRD_ATL_WI_2015 &rank=mrec&hs_sortBy=category&hs_o=desc (as of 10 Nov 2016).

[6] LGB&FR AOC Conservation Project Catalogue

[7] LGB&FR AOC comprehensive biota database: file "AOCBiota_DB_ShareableVersion_20171210.accdb".

[8] LGB&FR AOC 2016 botanical surveys

[9] LGB&FR AOC 2016 botanical surveys

Significant Animals	Significant animals that have been documented on the UW-Green Bay campus, unless otherwise noted:
	
	Birds:
	• ~180 bird species have been recorded across all seasons, including[4,5,7,10,11,12]:
	  o Two federal species of concern (Common Tern [*Sterna hirundo*] and Black Tern [*Chlidonias niger*])
	  o Four state endangered species (Caspian Tern [*Hydroprogne caspia*], Forster's Tern [*Sterna forsteri*], Common Tern, Black Tern, and Peregrine Falcon [*Falco peregrinus*])
	  o One state threatened species (Great Egret [*Ardea alba*])
	  o Twenty-nine Wisconsin Wildlife Action Plan Species of Greatest Concern (e.g., waterbirds, raptors, songbirds, and shorebirds)
	  o Thirty-two state special concern species (e.g., Swainson's Thrush [*Catharus ustulatus*], Cape May Warbler [*Setophaga tigrina*])
	  o Six International Union for Conservation of Nature-listed species as near threatened (Chimney Swift [*Chaetura pelagica*], Red-headed Woodpecker [*Melanerpes erythrocephalus*], Olive-sided Flycatcher [*Contopus cooperi*], Semipalmated Sandpiper [*Calidris pusilla*]) or vulnerable (Long-tailed Duck [*Clangula hyemalis*], Rusty Blackbird [*Euphagus carolinus*])
	  o Although many bird species migrate through the UW-Green Bay Cofrin Memorial Arboretum, generalist bird species tend to use it as a migratory stopover site, typically in the late fall.[10] Migratory waterfowl (e.g., diving ducks, gulls) use the waters offshore from the Cofrin Memorial Arboretum as stopover habitat[11]
	  o Over 40 bird species are known (or very likely) to breed within Bay Shore Woods and Beach and nearby vicinity[5,12]:
	    ▪ Red-bellied Woodpecker (*Melanerpes carolinus*), Pileated Woodpecker (*Dryocopus pileatus*), White-breasted Nuthatch (*Sitta carolinensis*), House Wren (*Troglodytes aedon*), Red-eyed Vireo (*Vireo olivaceus*), American Robin (*Turdus migratorius*), Song Sparrow (*Melospiza melodia*), etc.
	  o The UW-Green Bay campus is officially a "Migratory Bird Concentration Site" according to the Wisconsin Department of Natural Resources[13]
	
	Fish:
	• >30 fish species have been reported offshore of Bay Shore Woods and Beach by the WDNR during their long-term trawling surveys in recent years, including[14]:
	  o Emerald shiner (*Notropis atherinoides*)
	  o Spottail shiner (*Notropis hudsonius*)
	  o Channel catfish (*Ictalurus punctatus*)
	  o Black crappie (*Pomoxis nigromaculatus*)
	  o Yellow perch (*Perca flavescens*)
	  o Gizzard shad (*Dorosoma cepedianum*)
	  o Walleye (*Sander vitreus*)
	
	Mammals:
	• Although more are likely found here, >20 species have been officially documented[7,15]:

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[10] Stephanie Beilke migratory landbird thesis project

[11] LGB&FR AOC 2016 migratory waterfowl surveys

[12] LGB&FR AOC 2015 breeding bird surveys

[13] Wisconsin Department of Natural Resources. 2009. Wisconsin Natural Heritage Working List. http://dnr.wi.gov/topic/NHI/WList.html. (Accessed: 1 Nov 2014).

[14] Wisconsin Department of Natural Resources long-term fish trawling surveys

[15] Mahon Woods webpage from UW-Green Bay's Cofrin Center for Biodiversity: http://www.uwgb.edu/biodiversity/natural-areas/arboretum/mahon.asp.

	o Fur bearers: American mink (*Neovison vison*), red fox (*Vulpes vulpes*), short-tailed weasel or ermine (*Mustela erminea*), striped skunk (*Mephitis mephitis*), coyote (*Canis latrans*), etc. o Rodents: groundhog (*Marmota monax*), meadow vole (*Microtus pennsylvanicus*), etc. o Other: white-tailed deer (*Odocoileus virginianus*), masked shrew (*Sorex cinereus*), southern flying squirrel (*Glaucomys volans*), etc. <u>Amphibians</u>: • Two anuran (frog/toad) species were detected in April and June 2015 during surveys conducted by UW-Green Bay student researchers next to the small emergent inland wetland in the southwestern corner of Bay Shore Woods and Beach[7]: o Green frog (*Lithobates clamitans*) and wood frog (*Lithobates sylvaticus*) • Red-backed salamander (*Plethodon cinereus*)[15] <u>Reptiles</u>: • Five reptile species[7,16]: o Common garter snake (*Thamnophis sirtalis*), red-bellied snake (*Storeria occipitomaculata*), and milk snake (*Lampropeltis triangulum*) o Snapping turtle (*Chelydra serpentina*) and painted turtle (*Chrysemys picta*) <u>Arthropods</u>: • Within Bay Shore Woods and Beach priority area and neighboring land, 18 odonate species (dragonfly + damselfly) have been recorded here (commonality reported in relation to detections near this priority area)[17]: o Eastern forktail (*Ischnura verticalis*), relatively common o Autumn meadowhawk (*Sympetrum vicinum*), relatively common o Common green darner (*Anax junius*), relatively common o Twelve-spotted skimmer (*Libellula pulchella*), relatively common o Marsh bluet (*Enallagma ebruim*), relatively common o Ebony jewelwing (*Calopteryx maculata*), relatively common o Slender spreadwing (*Lestes rectangularis*), relatively uncommon o Dot-tailed whiteface (*Leucorrhinia intacta*), relatively uncommon o Sedge sprite (*Nehalennia irene*), rare
Habitat Quality	The overall ecological quality of Bay Shore Woods and Beach is relatively good because native plants dominate much of this priority area. Although invasive plants species can be found here, the hardwood swamp and shoreline are not completely overrun with invasive understory shrubs (e.g., buckthorn) or *Phragmites*. In fact, several important native plants occur here, including American basswood, sandbar willow, green ash, shagbark hickory, ostrich fern, and bulrush; though, the Great Lakes beach perhaps needs the most work in terms of controlling invasive plant species since several besides *Phragmites* occur here. The CCB should continue its efforts to control the invasive plants that frequent this priority area in order to further improve fish and wildlife habitat.
Significant Invasive Species Issues	Significant invasive species that have been documented within Bay Shore Woods and Beach: <u>Invasive Plant Species</u>: Each of these species outcompetes and crowds out native plants[2,8]: • European buckthorn (*Rhamnus cathartica*)

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[16] UW-Green Bay Cofrin Student Research Grant Project by Lindsey Bender and Gary Wauters 2010

[17] LGB&FR AOC Odonata Surveys 2016 by Willson Gaul

    - Common and continuing problem; found in understory of hardwood swamp; currently being managed
- Glossy buckthorn (*Frangula alnus*)
    - Common and continuing problem; found in understory of hardwood swamp; currently being managed
- Common reed (*Phragmites australis*)
    - Common and continuing problem; occurs along shoreline in emergent marsh and Great Lakes beach
- Showy bush honeysuckle (*Lonicera* × *bella*)
    - Common and continuing problem; occurs in hardwood swamp; currently being managed
- Crack willow (*Salix* × *fragilis*)
    - Occurs in hardwood swamp; not currently being managed
- Japanese barberry (*Berberis thunbergii*)
    - Occurs in hardwood swamp; not currently being managed
- Dame’s rocket (*Hesperis matronalis*)
    - Occurs in hardwood swamp; not currently being managed
- European lily-of-the-valley (*Convallaria majalis*)
    - Occurs in hardwood swamp; not currently being managed

<u>Exotic Plant Species</u>:[8]

- White mulberry (*Morus alba*)
    - Occurs in hardwood swamp; not currently being managed
- European cranberry-bush (*Viburnum opulus*)
    - Occurs in hardwood swamp; not currently being managed

<u>Invasive Animal Species</u>:[7]

- *Arthropods*:
    - Documented within or near UW-Green Bay campus (none are being managed):
        - Cobweb weaver (*Enoplognatha ovata*)
        - Common harvestman (*Phalangium opilio*)
        - Grey field slug (*Deroceras reticulatum*); considered to be an exotic species; effects on forest understories are not well known[18]
    - Japanese beetle (*Popilla japonica*) was documented using the Great Lakes beach habitat of Bay Shore Woods and Beach in July 2016[8]

- *Birds*: Documented within or near UW-Green Bay campus:
    - European Starling (*Sturnus vulgaris*)
        - Poses some threat to native species, particularly cavity nesters (e.g., Tree Swallow), by outcompeting them and occupying potential nest sites; not currently being managed
    - Other exotic or invasive bird species: House Sparrow (*Passer domesticus*) and Rock Pigeon (*Columba livia*); however, these species generally do not significantly affect native birds because they tend to inhabit human areas (e.g., developed or agricultural areas)

- *Fish*: Documented within or near UW-Green Bay campus:
    - Alewife (*Alosa pseudoharengus*)

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[18] Andrew LaPlant exotic slug abundance study in northeastern WI

	▪ Poses a threat to native fish species by consuming a lot of zooplankton and disturbing the natural food web; not currently being managed[19] ○ Common carp (*Cyprinus carpio*) ▪ Destroy vegetation by uprooting plants and increasing cloudiness of water; not currently being managed[20] ○ Round goby (*Neogobius melanostomus*) ▪ Prey on small native fish and eggs (e.g., darters) and outcompete similarly sized native fish; not currently being managed[21]
Management and Restoration Recommendations	• Control woody successional and invasive plant species, remove accumulated zebra/quagga mussel shells, and restore native vegetation at undeveloped east shore beaches. • Conduct biotic inventories along AOC shoreline and if necessary re-establish populations of native turtle species and other beach specialists. • Identify critical buffer habitats and shorelines with potential den sites for mink, otter, and other shoreline wildlife species. • Develop or restore important fish spawning and nursery habitats, such as rocky reefs, gravel, cobble, woody debris, and sandy areas for shoreline fish. • Continue current invasive plant species management efforts to control invasives noted above (e.g., buckthorn, showy bush honeysuckle). Restore and expand habitats with native fruiting shrubs to improve stopover habitat for migratory land birds. • Control *Phragmites* along the Great Lakes beach shoreline, including at the neighboring priority area, Mahon Woods and Creek, which will improve shorebird and other wildlife habitat. • Enhance small inland emergent marsh located in the southwestern corner of this priority area by controlling the *Phragmites* and restoring with native herbaceous vegetation.
Reference Links and Documents	**Links**: • UW-Green Bay's Cofrin Memorial Arboretum: http://www.uwgb.edu/biodiversity/natural-areas/arboretum/ **Reference Documents**: • Dorney, J.R. 1975 The vegetation pattern around Green Bay in the 1840s as related to geology, soils, and land use by Indians with a detailed look at the Townships of Scott, Green Bay, and Suamico. Book available through the UW-Green Bay Cofrin Library Archives and Area Research Center.
Site History (e.g., original vegetation, past conservation projects)	In the early 1630s, Frenchman Jean Nicolet first arrived in lower Green Bay when it was primarily inhabited by Native American tribes[22]. Lower Green Bay consisted of large beds of wild rice (*Zizania* sp.) and wild celery (*Vallisneria americana*), extensive emergent marsh (*Schoenoplectus* sp., cattail), sedge meadows (*Calamagrostis canadensis*), shrub carr (e.g., *Cornus* spp., *Salix* spp.), swamps, and wet conifer forest

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[19] 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.

[20] 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.

[21] 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.

[22] Jean Nicolet: French Explorer. By The Editors of Encyclopaedia Britannica. Available: https://www.britannica.com/biography/Jean-Nicolet (accessed on 24 Oct 2016).

(black spruce [*Picea mariana*], balsam fir [*Abies balsamea*])[23,24,25,26,27]. Between the late 1600s through the 1800s, European fur trade, hunting, fishing, logging, shipping, and agriculture were important early industries in lower Green Bay[28,29,30].

In the early 1800s, there were a few small settlements and farms consisting of Europeans and Native Americans in the lower bay[29,30]. In the early 1840s, Native American campsites and burial mounds were located within the present day UW-Green Bay campus[31]. Vegetation at present day UW-Green Bay in 1840 largely consisted of oak openings dominated by red and white oaks and burr oak (*Quercus macrocarpa*) with early successional, recently disturbed areas consisting of aspen (*Populus* spp.) and birch (*Betula* spp.)[31]. According to surveyors in June 1834, there was a house located within agricultural fields as well as open meadows in the southwestern part of Bay Shore Woods and Beach[32].

According to 1875 and 1889 Plat Books of Brown County, most of present day Bay Shore Woods and Beach was privately owned by John Woodruff[33,34]. Sometime before the mid-1930s, this same land was broken up into really small parcels that were privately owned[35]. It was almost entirely forested with emergent marsh along the shoreline and largely remained that way until present time[36]. Present day Lambeau Cottage was built along Bay Shore Woods and Beach in 1941 by Curly Lambeau, who helped found, coach, and play for the Green Bay Packers national football team[37]. Lambeau built this cottage primarily for recreational and entertainment purposes for the Green Bay Packers[37]. In 1950, he sold the property, which was eventually bought by UW-Green Bay in 1978. Today, the cottage is a part of the existing Cofrin Memorial Arboretum and is still used for many different entertainment functions[37].

In the 1960s, the state of Wisconsin owned the land known as Bay Shore Woods and Beach, and in 1965, UW-Green Bay was founded and established as a four-year college[38]. Although agricultural fields still dominated most of the campus property, there were still many important natural features, including Mahon Creek, forests, and the Niagara Escarpment[39]. In 1971, former Chancellor Edward Weidner and a small committee recommended that UW-Green Bay create a system of trails and an

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[23] Arthur C. Neville's Map of Historic Sites on Green Bay, Wisconsin 1669-1689. Available: http://s3.amazonaws.com/labaye/data/Bay%20Settle ment%20Map%20WI%20Historical%20Bulletin%201926.pdf (accessed on 24 Oct 2016).

[24] 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).

[25] 1845 Chart of Green Bay. Available http://s3.amazonaws.com/labaye/data/1845%20Chart%20of%20Green%20Bay.pdf (accessed on 24 Oct 2016).

[26] 1820s Fox River Military Road Map to Ft. Crawford. Available: http://s3.amazonaws.com/labaye/data/1820s%20Fox%20River%20Military%20 Road%20Map%20to%20Ft.%20Crawford.pdf (accessed on 24 Oct 2016).

[27] Personal communication with Thomas Erdman.

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

[29] 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).

[30] 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).

[31] The vegetation pattern around Green Bay in the 1840s as related to geology, soils, and land use by Indians with a detailed look at the Townships of Scott, Green Bay, and Suamico by John Dorney, 1975. File "Dorney1975_VegetationPatternGreenBay1840s.pdf".

[32] Wisconsin Public Land Survey System (1834) from file "PLSS_SurveyData.shp".

[33] 1875 Brown County plat map. Available through the UW-Green Bay Cofrin Library Archives and Area Research Center.

[34] 1889 Brown County plat map. Available through the UW-Green Bay Cofrin Library Archives and Area Research Center.

[35] 1934-1936 Brown County plat map for the Town of Scott. Available through the UW-Green Bay Cofrin Library Archives and Area Research Center.

[36] Brown County's Multi-purpose GIS map and 1938 aerial photograph. Available: http://www.co.brown.wi.us/departments/page_7f0c2fbe 6bc6/?department=85713eda4cdc&subdepartment=89ce08984445 (accessed on 29 Nov 2016).

[37] UW-Green Bay History with the Green Bay Packers: https://www.uwgb.edu/packers/history/ (accessed on 29 Nov 2016).

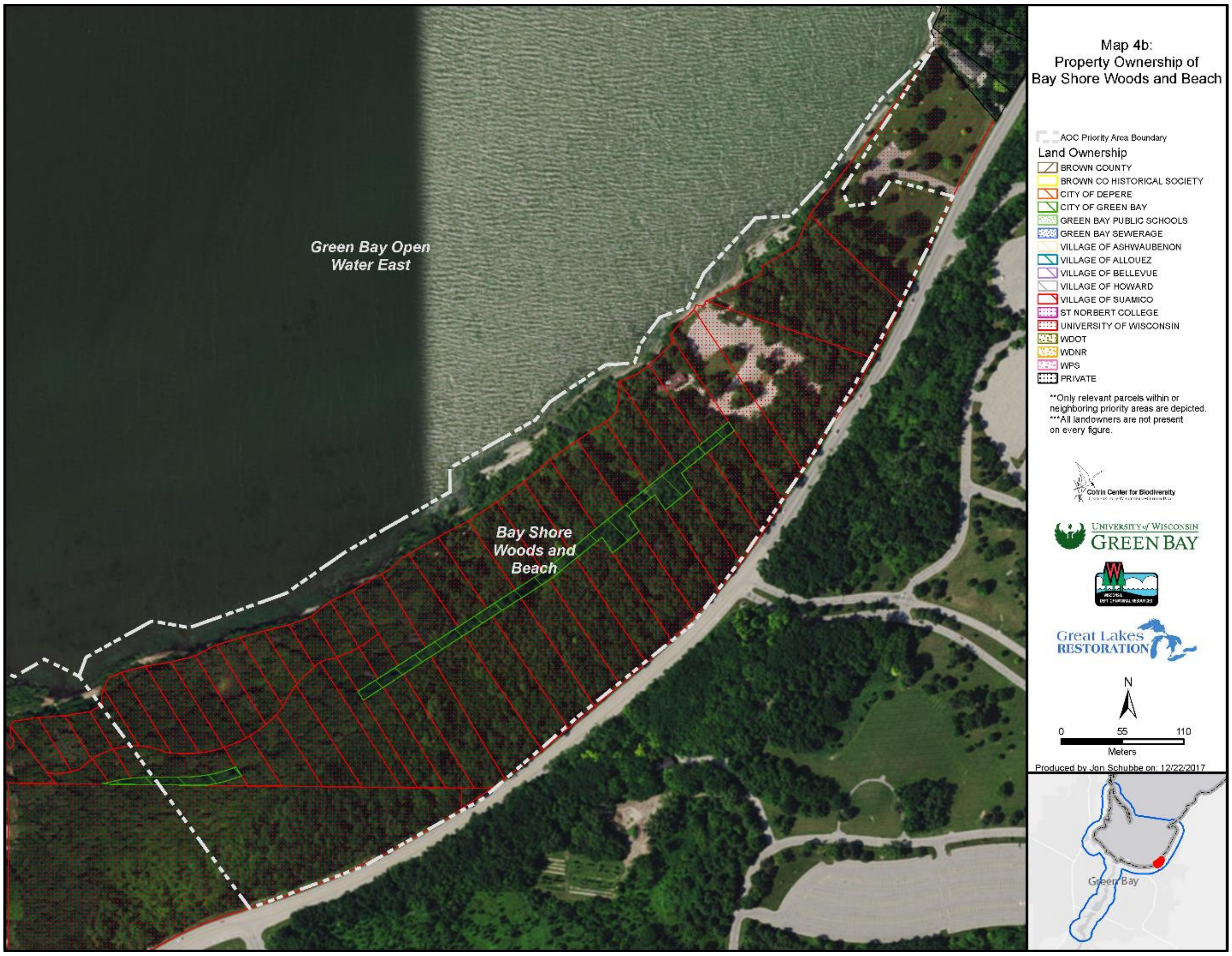
[38] UW-Green Bay: From the Beginning by Betty D. Brown webpage: http://www.uwgb.edu/univcomm/from-the-beginning/ (accessed on 15 Nov 2016).

[39] History of the Arboretum: http://www.uwgb.edu/biodiversity/natural-areas/arboretum/History.asp (accessed on 15 Nov 2016).

	arboretum that circled the campus in an effort to prevent future development on campus and to keep it natural[39]. Thanks to the family of John Cofrin, an endowment was established to pay for the building of these hiking trails, enhance the natural communities, and purchase additional adjacent property to develop what is today called the Cofrin Memorial Arboretum[39]. The present day Bay Shore Woods and Beach priority area is just one small section of the larger arboretum, which also includes the Keith White Prairie, Mahon Woods, northern barrens, Niagara Escarpment, oak savanna, Paul Sager tract, succession plots, and Les Raduenz Woods[39]. After the UW-Green Bay Cofrin Center for Biodiversity (CCB) was established in 1999, one of its responsibilities was to manage the campus natural areas (e.g., Point au Sable Nature Preserve), which included the Cofrin Memorial Arboretum. Today, the CCB manages the Cofrin Memorial Arboretum by controlling invasives, preserving the natural communities found there, and maintaining trails. Although this priority area is relatively well studied (at least for plants, fish, birds, and some arthropods) by the University and agencies, additional studies are needed for mammals, reptiles (e.g., turtles), and amphibians (e.g., salamanders). It provides critical habitat for both plants and many wildlife, particularly migratory and breeding birds, odonates, and others. To improve existing wildlife habitat, CCB staff have been actively trying to control invasive plant species, such as understory woody plants (e.g., buckthorn), in the hardwood swamp forest. They are also working to control the *Phragmites* found along the Great Lakes beach shoreline of this priority area, which is important because it is part of a longer stretch of beach habitat, which is rare to both the state of WI and the LGB&FR AOC. Because this priority area is protected and almost entirely publicly owned by the University, there is great potential to enhance this property for fish and wildlife habitat. It is also one of the few relatively undeveloped areas along the east shore of lower Green Bay. Therefore, efforts should be made to continue protecting and preserving this property in order to sustain fish and wildlife populations within the LGB&FR AOC.

Map of Bay Shore Woods and Beach plant communities, which are delineated based on the UW-Green Bay 2015 habitat mapping effort. Map made by UW-Green Bay’s Jon Schubbe.

Land ownership boundaries at Bay Shore Woods and Beach. Map made by UW-Green Bay's Jon Schubbe.



Photograph of Bay Shore Woods and Beach facing southeast. Photograph taken by Erin Giese on 2 December 2016.

Photograph of Bay Shore Woods and Beach facing southeast. Photograph taken by Erin Giese on 2 December 2016.

Appendix 10.5: Cat Island

Written by Erin Giese and James Horn

<table>
<tr><td>Location (centroid)</td><td>Lat. 44.566961°, Lon. -88.008842°[1] (NAD 1983, UTM Zone 16N)</td></tr>
<tr><td>Total Area (ha)</td><td>152.50 ha</td></tr>
<tr><td>Area Public Land (ha)</td><td><p>0 ha</p><p>The Cat Island Wave Barrier is currently owned by the Brown County Port and Recovery office in Green Bay, and the U.S. Army Corps of Engineers (USACE) is actively filling the reconstructed island “cells” with shipping channel dredge material. The USACE will continue to fill these “cells” over the next 20-30 years. Because it is an active construction site and because the recently placed dredge material can behave like quick sand, it is considered to be dangerous and poses a serious safety hazard. The causeway/wave barrier is gated and locked at two locations.</p><p>Therefore, there is <u>no public access</u> available at this time.</p></td></tr>
<tr><td>Area of Habitat Types Present (ha) and Percent of Each Habitat Type</td><td><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&FR AOC)[2]. Habitat types within Cat Island are displayed as a static map at the bottom of this document. There is a total of 132.30 ha of natural habitat within Cat Island.</p>
<table>
<tr><th>Habitat Type</th><th>Area (ha)</th><th>Percent</th></tr>
<tr><td>Emergent Marsh (High Energy Coastal)</td><td>0.01</td><td>0.01</td></tr>
<tr><td>Great Lakes Beach</td><td>10.83</td><td>8.18</td></tr>
<tr><td>Green Bay Open Water</td><td>121.05</td><td>91.50</td></tr>
<tr><td>Submergent Marsh</td><td>0.42</td><td>0.32</td></tr>
</table>
<p><i>Disclaimer!</i> <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 all habitats listed above are known to fluctuate significantly from year to year and within years. Moreover, because the Cat Island Project is an active construction site with ever-changing dredge placement, the amount of Great Lakes beach in particular will vary greatly over time. 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 of 2016 and 2017. Great Lakes water levels were much higher in 2016 and 2017 than in July 2015.</i></p></td></tr>
<tr><td>General Description</td><td>The Cat Island Wave Barrier is a ~4.5 km long causeway that extends into the open bay of Green Bay from Peters Marsh along the southern west shore. Off the causeway/wave barrier, are three artificial island “cells” with “legs” extending off the main road/causeway[3]. Historically, there were three large barrier islands (i.e., the Cat Island Chain) that provided critical fish and wildlife habitat for birds, fish, invertebrates, and furbearers and offered a protected refugium for native plants and extensive Great Lakes beach[3]. These islands were very popular to duck hunters as well[4]. Due to</td></tr>
</table>

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[1] File “AOC_PriorityAreas_v09_USE_THIS.shp”

[2] LGB&FR AOC 2015 habitat field mapping effort

[3] Brown County Port and Resource Recovery Cat Island document: https://static1.squarespace.com/static/56ec0372859fd0e272858772/t/574db48fab48de7bc23597a0/1464710289702/2014+Cat+Island+Abstract+Spring.pdf

[4] Personal communication with Thomas Erdman on 13 January 2016

	extremely high water levels in the bay, massive storms, and hardened shorelines, these islands washed away during the spring of 1973 with the exception of a few small sandy islands, including parts of Cat Island[3,5]. 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 because of high sediment loads further upstream[3,5]. 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[3]. It took decades of extensive planning and acquiring funding for that idea to materialize and become a reality[3,6]. They collaborated with Brown County, Brown County Port and Resource Recovery Office, and U.S. Army Corps of Engineers (USACE) and decided to reconstruct these islands. Over time, the Cat Island Wave Barrier and island "cells" were eventually constructed by May 2013[3]. Although the project will not be fully completed for another 20-30 years, many fish and wildlife have already been documented using the relatively new dredge material, which consists of sand and clay, in the westernmost island "cell," including the federally and state endangered shorebird, the Piping Plover (*Charadrius melodus*). Piping Plovers have not been recorded nesting in lower Green Bay in over 70 years and were only previously known to nest on Longtail Point and Little Tail Point[4]. This project site is also currently considered the best shorebird migratory stopover site in the entire state of Wisconsin. While the project is far from completion, it offers many unique opportunities for wildlife managers and researchers to explore adaptive management techniques, such as constructing tern nesting platforms, testing out different nesting substrate for Piping Plovers, and restoring native submergent and emergent plants in the shadow of the wave barrier[7]. Many research projects are currently taking place as scientists and managers explore the re-establishment of submergent and aquatic plants and the responses of fish and wildlife. This project provides an excellent example of conservationists and resource managers working together to solve problems and achieve success through collaboration, communication, and identifying common ground.
Special Features	• Contains a significant amount of Great Lakes beach habitat, which is rare to both the state of WI and the LGB&FR AOC. • Provides the submergent and emergent marshes of the Duck Creek Delta and Peters Marsh wetland complexes with protection from wave action. • Provides breeding habitat for many colonial nesting birds, including American White Pelican (*Pelecanus erythrorhynchos*), Double-crested Cormorant (*Phalacrocorax auritus*), Caspian Tern (*Hydroprogne caspia*), Common Tern (*Sterna hirundo*), Herring Gull (*Larus smithsonianus*), Ring-billed Gull (*Larus delawarensis*), herons/egrets, and the federally and state endangered Piping Plover (*Charadrius melodus*). • Open water surrounding the Cat Island Wave Barrier provides habitat for many fish species. • Provides migratory shorebird habitat and is currently considered to be the most critical shorebird migratory stopover site in Wisconsin[8]. • Offers important migratory stopover habitat for waterfowl and staging habitat for swallows and blackbirds on the Great Lakes beach habitat[9]. • Provides wintering bird habitat to Snowy Owls, Snow Buntings (*Plectrophenax nivalis*), and some waterfowl.
Natural Habitat Communities and	There is nearly 11 ha of **Great Lakes beach habitat** within the boundaries of this priority area found both in the existing historic Cat Island as well as the recently

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[5] Frieswyk and Zedler 2007: "Vegetation change in Great Lakes coastal wetlands: deviation from the historical cycle"
[6] U.S. Dept. of the Interior Article: https://www.doi.gov/restoration/restoring-cat-island-chain-green-bay-wisconsin
[7] UW-Sea Grant Webpage: http://www.seagrant.wisc.edu/home/Portals/0/Files/Habitats%20and%20Ecosystems/CatIslandsRept.pdf
[8] Shorebird master's project by UW-Green Bay graduate student, Tom Prestby (2016)
[9] AOC Waterfowl Surveys in 2016-2017; surveys conducted by Tom Prestby

Significant Plants (ordered in terms of ecological importance and size/amount)	deposited dredge material. The existing Cat Island that sits inside the easternmost artificial "cell" is covered almost entirely by sand with little to no vegetation and has a small pond in the southwestern corner of the island. Due to the thousands of breeding American White Pelicans and Double-crested Cormorants, which produce significant amounts of guano, very few plants can thrive on this island. In contrast, parts of the westernmost "cell," which has relatively new dredge material that is largely sand, are heavily vegetated. Cottonwood (*Populus deltoides*) saplings have taken over the western and southwestern most parts of this "cell," though a diversity of other vascular plants—65 species total, including 45 native species—were also found there in a 2017 survey, including the following native species: • American sea-rocket (*Cakile edentula* ssp. *edentula* var. *lacustris*) • Dock-leaved smartweed (*Persicaria lapathifolia*) • Swamp milkweed (*Asclepias incarnata*) • Common milkweed (*Asclepias syriaca*) • Blue vervain (*Verbena hastata*) • Common yellow-cress (*Rorippa palustris*) • Common bur-reed (*Sparganium eurycarpum*) • Common water-parsnip (*Sium suave*) • Cypress-like sedge (*Carex pseudocyperus*) Throughout the rest of this priority area is a large amount of **open water**, since this is an active, ongoing project of placing dredge material, with pockets of **submergent** and **emergent marsh**.
Significant Animals	**Birds**: • 233 bird species have been recorded along the Cat Island Causeway and neighboring areas, including[10]: o One federally endangered species (Piping Plover) o One federally threatened species (Red Knot [*Calidris canutus*]) o Two federally listed species of concern (Black Tern [*Chlidonias niger*] and Common Tern [*Sterna hirundo*]) o Seven state endangered species: ▪ Black Tern, Common Tern, Caspian Tern (*Hydroprogne caspia*), Forster's Tern (*Sterna forsteri*), Peregrine Falcon (*Falco peregrinus*), Piping Plover, and Red-necked Grebe (*Podiceps grisegena*) o Two state threatened species (Great Egret [*Ardea alba*] and Upland Sandpiper [*Bartramia longicauda*]) o 44 state listed special concern species (e.g., American White Pelican, Buff-breasted Sandpiper [*Tryngites subruficollis*], Yellow-headed Blackbird [*Xanthocephalus xanthocephalus*], Ruddy Duck [*Oxyura jamaicensis*]) o Nine International Union for Conservation of Nature-listed species as vulnerable (e.g., Long-tailed Duck [*Clangula hyemalis*]) or near threatened (e.g., Semipalmated Sandpiper [*Calidris pusilla*]) o 39 Wisconsin Wildlife Action Plan Species of Greatest Concern (e.g., Wilson's Phalarope [*Phalaropus tricolor*]) o 33 species listed under the Partners in Flight priorities from Bird Conservation Regions 12 and 23 and Continental Watch List species o Seven species listed as regional priorities from the North American Waterfowl Management Plan o Several species are currently known to breed at this priority area, including[11,12]: ▪ American White Pelican

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[10] LGB&FR AOC comprehensive biota database: file "AOCBiota_DB_ShareableVersion_20171210.accdb"
[11] Wisconsin Breeding Bird Atlas II Project: https://wsobirds.org/atlas
[12] Personal communication with Thomas Prestby

        - Double-crested Cormorant
        - Ring-billed Gull
        - Herring Gull
        - Caspian Tern
        - Common Tern (only on artificial nesting platforms)
        - Forster’s Tern (only on artificial nesting platforms)
        - Piping Plover
        - Black-crowned Night-Heron (*Nycticorax nycticorax*)
        - Spotted Sandpiper (*Actitis macularius*)
        - Killdeer (*Charadrius vociferus*)
    - The waters surrounding the Cat Island Wave Barrier are also used by thousands of staging waterfowl during spring and fall migration[9]
    - Swallows use the open Great Lakes beach habitat and causeway for foraging and staging habitat shortly after the breeding season and during migration
    - >30 shorebird species use the open mud flats and edges of the causeway for foraging and stopover habitat[8]

Fish:

- Although >80 fish species have been recorded in the pelagic zone of the lower bay, some of which may use areas near Cat Island, only a few official records are available at this time. Species that use the bay, include[10]:
    - 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): redside dace (*Clinostomus elongatus*) and lake sturgeon (*Acipenser fulvescens*)

Mammals:

- Within the past two years, coyote (*Canis latrans*), red fox (*Vulpes vulpes*), and muskrat (*Ondatra zibethicus*) have been seen along the Cat Island Wave Barrier and neighboring waters. American mink (*Neovison vison*) has been found ~100 m north of the second locked, gate[10,12].

Anurans:

- Five anuran (frog/toad) species have been recorded[10]:
    - American toad (*Bufo americanus*), eastern gray treefrog (*Hyla versicolor*), northern leopard frog (*Lithobates pipiens*), spring peeper (*Pseudacris crucifer*), and American bullfrog (*Lithobates catesbeianus*)
    - Northern leopard frog is both a federal and state species of special concern. American bullfrog is a state species of special concern

Mollusks:

- A few snails have been reported at Cat Island from the following taxonomic groups[10]:
    - Genus: *Fossaria*, *Promenetus*, *Pseudosuccinea*, and *Stagnicola*
    - Family: Lymnaeidae, Physidae, and Planorbidae

Arthropods:

- Several insects have been recorded using the Cat Island Wave Barrier and neighboring areas, including[10]:
    - Hairy-necked tiger beetle (*Cicindela hirticollis rhodensis*), which is state endangered

	○ Slender spreadwing (*Lestes rectangularis*) ○ Lance-tipped darner (*Aeshna constricta*) ○ White-faced meadowhawk (*Sympetrum obtrusum*) ○ Familiar bluet (*Enallagma civile*) ○ Common green darner (*Anax junius*) ○ Beetles of families Hydrophilidae and Dytiscidae **Diatoms**: • Over 80 species of diatoms have been found near this priority area[10]
Habitat Quality	Overall, the ecological quality of the Great Lakes beach habitat is relatively low. While native plants have colonized the westernmost "cell" in the newly placed dredge material, cottonwood has rapidly taken over large stretches of this beach. Regular management is needed to handle both the cottonwood as well as other invasives that have been reported here, such as the common reed (*Phragmites australis*) and hybrid cattail (*Typha* × *glauca*).
Significant Invasive Species Issues	**Invasive Plant Species**: Of the 65 vascular plant species documented in a 2017 survey, 20 are introduced (not native), including several species with strong invasive potential. Each of the following species outcompetes and crowds out native plants[10]: • Common reed (*Phragmites australis*) • Hybrid cattail (*Typha* × *glauca*) • Purple loosestrife (*Lythrum salicaria*) • Common mouse-ear chickweed (*Cerastium fontanum*) • Narrowleaf hawk's-beard (*Crepis tectorum*) • Prickly sow-thistle (*Sonchus asper*) • Small peppergrass (*Lepidium densiflorum*) • White poplar (*Populus alba*) **Other Plant Issues**: Cottonwood saplings and other early successional species have taken over the western and southwestern most parts of this "cell," thus preventing other more desirable Great Lakes beach plants, such as American sea-rocket, from establishing. **Invasive Animal Species**: • *Birds*: Although five invasive birds have been reported at or near this priority area, these species pose little to no threat to native birds nesting along the Cat Island Wave Barrier since a completely different native group of birds nest there. These invasives are also closely associated with humans near development or agricultural areas[10]. No management is needed. ○ European Starling (*Sturnus vulgaris*) ○ House Sparrow (*Passer domesticus*) ○ Mute Swan (*Cygnus olor*), it is possible that they may destroy submerged aquatic plants ○ Ring-necked Pheasant (*Phasianus colchicus*) ○ Rock Pigeon (*Columba livia*) • *Fish*: Recorded in the pelagic zone of the lower bay[10]. ○ Alewife (*Alosa pseudoharengus*)[13] ▪ Poses a threat to native fish species by consuming zooplankton and disturbing the natural food web; not currently being managed. ○ Common carp (*Cyprinus carpio*)[14]

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[13] 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.

[14] 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.

	▪ Destroy vegetation by uprooting plants and increasing cloudiness of water; not currently being managed. o Rainbow smelt (*Osmerus mordax*)[15] ▪ Negatively affect uncommon to rare native fish species; not currently being managed. o Round goby (*Neogobius melanostomus*)[16] ▪ Prey on small native fish and eggs (e.g., darters) and outcompete similarly sized native fish; not currently being managed. o White perch (*Morone americana*)[17] ▪ Prey on native fish eggs, such as walleye; not currently being managed.
Management and Restoration Recommendations	• Develop and implement Cat Island Habitat and Wildlife Management Plan that addresses invasive plant species control (including native cottonwood), strategic placement of dredge material, public access restrictions, predator control, shoreline management, etc. • Construct and maintain permanent island structures for nesting colonial waterbirds, especially endangered terns. • Maintain large stretches of undisturbed Great Lakes beach habitat for disturbance-prone nesting Piping Plovers. • Continue exploring the restoration of aquatic and submergent plants in the wave shadow of the Cat Island Wave Barrier. • Conduct biotic inventories along AOC shoreline and if necessary re-establish populations of native turtle species and other beach specialists. • Develop or restore important fish spawning and nursery habitats, such as rocky reefs, gravel, cobble, woody debris, and sandy areas for shoreline fish. • Designate Cat Island as a sensitive coastal landscape. • Identify and protect safe roosting areas for wintering Snowy Owls, Snow Buntings, Bald Eagles, and others. • Create and manage intermittently flooded shoreline habitat for shorebirds on Green Bay islands and shoals. • Locate and protect heron rookeries; inform land managers and provide guidance for protection measures. • Place woody debris for fish habitat.
Reference Links and Documents	**Links**: • For more information on the Cat Island Project, please visit the following webpages: o Port of Green Bay website: http://www.portofgreenbay.com/cat-island-restoration-project/ o Abstract: https://static1.squarespace.com/static/56ec0372859fd0e272858772/t/574db48fab48de7bc23597a0/1464710289702/2014+Cat+Island+Abstract+Spring.pdf o Management Plan: https://static1.squarespace.com/static/56ec0372859fd0e272858772/t/574db4bc2eeb819c6640ce16/1464710333514/Final+Draft+Cat+Island+Management+Plan.pdf

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[15] 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.

[16] 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.

[17] 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.

	○ Operation and Maintenance Manual: https://static1.squarespace.com/static/56ec0372859fd0e272858772/t/574db456ab48de7bc23594f0/1464710259772/Cat+Island+O+and+M+Manual+Draft.pdf • 1845 Map of Green Bay, which shows the historic barrier islands: http://s3.amazonaws.com/labaye/data/1845%20Head%20Of%20Green%20Bay.pdf • 1938 and 1960 Aerial Imagery provided by the Brown County GIS Department: http://maps.gis.co.brown.wi.us/geoprime/#xmin=73606.12499999994;ymax=599938.75;ymin=573456.25;xmax=130984.87499999994 **Reference Documents**: • Bosley, T.R. 1978. Loss of wetlands on the west shore of Green Bay. Wisconsin Academy of Sciences, Arts, and Letters 66:235-245. • Dorney, J.R. 1975 The vegetation pattern around Green Bay in the 1840s as related to geology, soils, and land use by Indians with a detailed look at the Townships of Scott, Green Bay, and Suamico. Book available through the UW-Green Bay Cofrin Library Archives and Area Research Center. • Frieswyk, C.B. and J.B. Zedler. 2007. Vegetation change in Great Lakes coastal wetlands: deviation from the historical cycle. Journal of Great Lakes Research 33(2):366-380. • Howlett Jr., G.F. 1974. The rooted vegetation of west Green Bay with reference to environmental change. Master's thesis. University of Wisconsin-Green Bay. • Kupsky, B. and M. Dornbush. 2017. Cat Island and Duck Creek Delta Restoration: Restoring Green Bay Aquatic Vegetation Final Report. Final report submitted to Ducks Unlimited in January 2017. • U.S. Army Corps of Engineers. 2010. Environmental Assessment: Dredged Material Management Plan, Green Bay Harbor, Wisconsin.
Site History (e.g., original vegetation, past conservation projects)	In the early 1630s, Frenchman Jean Nicolet first arrived in lower Green Bay when it was primarily inhabited by Native American tribes[18]. Between the late 1600s and 1800s, European fur trade, duck hunting, fishing, logging, shipping, and agriculture were important early industries in lower Green Bay[19,20,21]. In the early 1800s, there were a few small settlements and farms of Europeans and Native Americans in the lower Bay[20]. Historically, there were three large barrier islands (called the Cat Island Chain) that provided critical fish and wildlife habitat for birds, fish, invertebrates, and mammals as well as refugia of native plants and extensive Great Lakes beach[3]. The most common waterfowl that historically bred in Green Bay included Blue-winged Teal (*Anas discors*), Pied-billed Grebe (*Podilymbus podiceps*), Gadwall, and Mallard (personal communication with Tom Erdman). Many different bird species nested on the islands of the Cat Island Chain, including Common Tern, Herring Gull, Ring-billed Gull, Black-crowned Night-Heron, Snowy Egret (*Egretta thula*), Cattle Egret (*Bubulcus ibis*), Gadwall (*Anas strepera*), Spotted Sandpiper, Mallard (*Anas platyrhynchos*), and Canada Goose (*Branta canadensis*; field notes from Tom Erdman, 1 June 1969 and 1995 video). Like other parts of the lower bay, the center of this barrier island chain was also used for dumping dredge spoils, as noted in the U.S. Army Corps of Engineers map from 1966[27], a relatively common practice prior to environmental laws requiring dredge spoils to be dumped in confined areas. These islands also protected a massive complex of emergent and submergent marshes in the Duck Creek Delta,

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[18] Jean Nicolet: French Explorer. By The Editors of Encyclopaedia Britannica. Available: https://www.britannica.com/biography/Jean-Nicolet (accessed on 24 Oct 2016).

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

[20] 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).

[21] 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).

	including Peters Marsh. The true size and extent of the marsh complex that the Cat Island Chain protected can best be appreciated by looking at 1938 and 1960 aerial imagery (provided by Brown County's online GIS portal)[22]. Overall, lower Green Bay consisted of large beds of wild rice (*Zizania* sp.) and wild celery (*Vallisneria americana*), extensive emergent marsh (*Schoenoplectus* sp., cattail), meadows, sedge meadows (*Calamagrostis canadensis*), shrub carr (e.g., *Cornus* spp., *Salix* spp.), swamps, and wet conifer forest (black spruce [*Picea mariana*], balsam fir [*Abies balsamea*])[23,24,25,26,27,28]. However, due to extremely high water levels in the bay, massive storms, and recently hardened shorelines (e.g., development), these islands washed away during the spring of 1973 with the exception of a few small sandy islands, including Cat Island[3,29]. 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[3,5]. These significant changes can easily be viewed on Brown County's 1978 aerial imagery of lower Green Bay[22]. 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[3]. It took decades for that idea to materialize and became a reality, but it finally happened[3]. Conservationists collaborated with Brown County, Brown County Port and Resource Recovery Office, and U.S. Army Corps of Engineers (USACE) and decided to reconstruct these islands on the basis of three primary reasons[3]. Two reasons were to restore the obvious loss of island fish and wildlife habitat but also provide adequate protection from wave action in order to improve growing conditions for aquatic and submergent plants[3]. The third purpose was because the Port of Green Bay needed more storage for dredge material from the shipping channel dredging effort, and the cells from the causeway provided just that[3]. 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[3,6]. Besides the USACE and Port of Green Bay, many partners have been involved in this project, including Brown County, Wisconsin Department of Natural Resources (WDNR), U.S. Fish and Wildlife Service (FWS), UW-Sea Grant, UW-Green Bay, Lower Fox River/Green Bay Natural Resources Trustee Council, and many port terminal operators[3]. So far, a relatively large amount of dredge material has been placed in the westernmost "cell" off the causeway though some material has also been placed in the middle cell. Although the project will not be fully completed for another 20-30 years, many fish and wildlife have already been documented using the relatively new dredge material, which

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[22] Brown County's Online GIS Portal: http://maps.gis.co.brown.wi.us/geoprime/#xmin=85453.16361768021;ymax=592329.2851743905;ymin=578954.2851743905;xmax=114432.33028434687

[23] Arthur C. Neville's Map of Historic Sites on Green Bay, Wisconsin 1669-1689. Available: http://s3.amazonaws.com/labaye/data/Bay%20Settle ment%20Map%20WI%20Historical%20Bulletin%201926.pdf (accessed on 24 Oct 2016).

[24] 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).

[25] 1845 Chart of Green Bay. Available http://s3.amazonaws.com/labaye/data/1845%20Chart%20of%20Green%20Bay.pdf (accessed on 24 Oct 2016).

[26] 1820s Fox River Military Road Map to Ft. Crawford. Available: http://s3.amazonaws.com/labaye/data/1820s%20Fox%20River%20Military%20 Road%20Map%20to%20Ft.%20Crawford.pdf (accessed on 24 Oct 2016).

[27] Personal communication with Thomas Erdman.

[28] 1845 Map of western lower Green Bay. Available: http://browncounty.maps.arcgis.com/apps/StorytellingSwipe/index.html?appid=72615351 ef33434e9a6a1bb5fffdbe9c&webmap=02074b6abfc44b88bfe9e96afe90a014 (accessed on 28 Oct 2016).

[29] Frieswyk and Zedler 2007: "Vegetation change in Great Lakes coastal wetlands: deviation from the historical cycle"

consists of sand and clay, in the westernmost island "cell," including the federally and state endangered shorebird, the Piping Plover. Piping Plover has not been recorded nesting in lower Green Bay in over 70 years. One pair fledged four chicks from the westernmost "cell" in 2016, and four pairs nested in 2017. The FWS and WDNR organized Piping Plover nesting monitoring throughout the breeding season and enlisted many volunteers. This project site is also currently considered the best migratory shorebird stopover site in the entire state of Wisconsin with reports of >30 different shorebird species. Many diving and dabbling ducks and other waterfowl utilized the neighboring waters during migration[9].

While the project is far from completion, it offers many unique opportunities for wildlife managers and researchers to study changes and explore adaptive management techniques, such as constructing tern nesting platforms, testing out different nesting substrate for Piping Plovers, restoring native submergent and emergent plants in the shadow of the wave barrier, and possibly building fish reefs[30]. Within the past few years, the FWS, WDNR, UW-Green Bay, and others have been meeting to discuss long-term habitat and wildlife management plans, such as building permanent tern nesting structures, Piping Plover protection and predator management, vegetation management (i.e., control invasives and cottonwood), and other topics.

A couple of times a year, the Cat Island Advisory Committee (CIAC) meets to discuss dredging updates, wildlife protection, research, and other topics with the USACE, Brown County, and others. The meetings are organized by Mark Walter and Dean Haen from Brown County, and so far the CIAC has written and published a public access document as well as a general management plan[31].

While dredge material has been placed in two of the three "cells," the material is by no means permanent. The backsides of the "cells" are currently open, which can cause the material to settle and move within the "cell" walls. The USACE will also need to move the material around over time. However, conservationists are working with the USACE on exploring different options for better containing the dredge material. 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 shifting to emergent and submergent marshes.

With the past several years, several research projects have taken place on the Cat Island Wave Barrier as well as in the wave shadow within the Duck Creek Delta.

- Study on water quality, seed bank, and hard-stem bulrush (*Schoenoplectus acutus*) plantings in front of and behind the Cat Island Wave Barrier in 2013 by UW-Green Bay graduate student Tim Flood; major advisor: Dr. Patrick Robinson.
- Aquatic plant restoration project (2015-2016) in Peters Marsh just inside the Cat Island Wave Barrier by UW-Green Bay graduate student Brianna Kupsky; major advisor: Dr. Mathew Dornbush.
- The FWS coordinates an early detection and monitoring program of aquatic invasive species in Lake Michigan, and many of their sampling locations are in the LGB&FR AOC, including this priority area[32]. They survey for ichthyoplankton, carp, macroinvertebrates, and nearshore fishes[32].
- Baseline shorebird study (2013-2014) in lower Green Bay, including sites on the Cat Island Wave Barrier, by UW-Green Bay graduate student, Tom Prestby; major advisor: Dr. Robert Howe.
- 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.

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[30] UW-Sea Grant Webpage: http://www.seagrant.wisc.edu/home/Portals/0/Files/Habitats%20and%20Ecosystems/CatIslandsRept.pdf

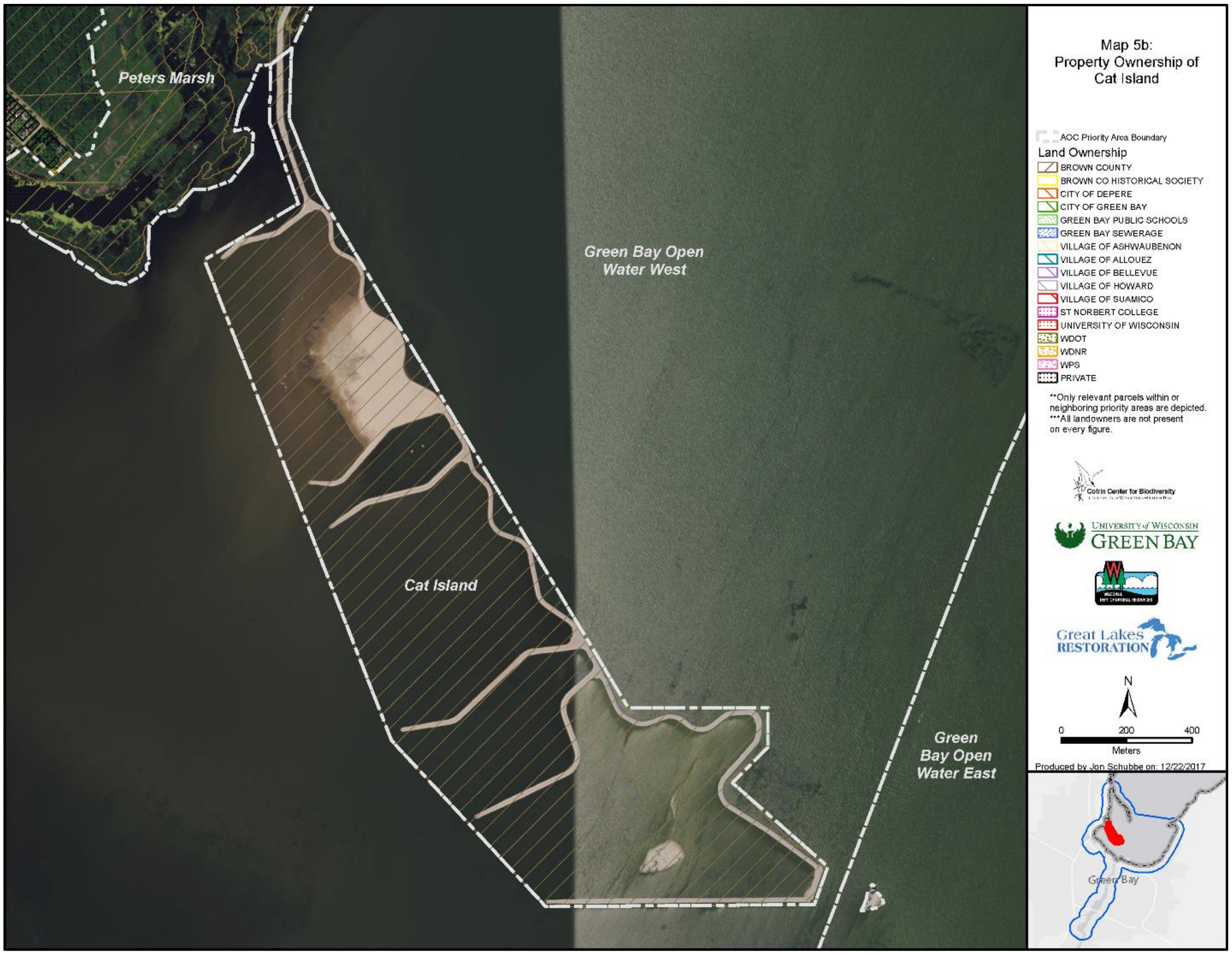
[31] Cat Island Management Plan: https://static1.squarespace.com/static/56ec0372859fd0e272858772/t/574db4bc2eeb819c6640ce16/1464710333514/Final+Draft+Cat+Island+Management+Plan.pdf

[32] Green Bay Fish Working Group Annual Meetings on 4 January 2017

	Patrick Robinson (UW-Green Bay), Dr. Mathew Dornbush (UW-Green Bay), and Brian Glenzinski (Ducks Unlimited). • Migratory waterfowl surveys in the LGB&FR AOC, including sites on the Cat Island Wave Barrier[9]; surveys conducted by Tom Prestby; project leads: Dr. Robert Howe, Dr. Amy Wolf, and Erin Giese. • Marshbird and anuran surveys on the Cat Island Wave Barrier and Peters Marsh for the Great Lakes Coastal Wetland Monitoring Program; Dr. Robert Howe (Principal Investigator) and Erin Giese (Project Coordinator). • NEW Water collects water quality monitoring data from a station just off the easternmost "cell" next to the shipping channel. Over the next 20-30 years, new research, adaptive management, and collaborations with Brown County and the USACE will likely bring exciting new conservation opportunities and the chance to create greatly needed fish and wildlife habitat within the LGB&FR AOC.

Map of Cat Island 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.

Land ownership boundaries at Cat Island. Map made by UW-Green Bay's Jon Schubbe.



Photograph of the Cat Island Wave Barrier facing southwest towards the mouth of Duck Creek. Photograph taken by Erin Giese on 2 December 2016.

Photograph of the Cat Island Wave Barrier facing southwest, featuring the westernmost cell, which has been filled with sandy dredge material within the last few years. Photograph taken by Erin Giese on 2 December 2016.

Photograph of the Cat Island Wave Barrier facing southwest, featuring the middle "cell," which was recently filled with dredge material and historic Cat Island in the upper left. Photograph taken by Erin Giese on 2 December 2016.

Photograph of the original Cat Island inside the easternmost "cell" of the Cat Island Wave Barrier facing east. Photograph taken by Erin Giese on 2 December 2016.

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

Appendix 10.6: Dead Horse Bay

Written by Erin Giese and James Horn

<table>
<tr><td>Location (centroid)</td><td>Lat. 44.610301°, Lon. -88.006404°[1] (NAD 1983, UTM Zone 16N)</td></tr>
<tr><td>Total Area (ha)</td><td>167.79 ha</td></tr>
<tr><td>Area Public Land (ha)</td><td>The boundaries of the Dead Horse Bay priority area are located within the coastal zone/waters of the bay of Green Bay and are thus public. Depending on lake levels, parts of the west shore and Longtail Point may overlap with the boundaries of the Dead Horse Bay priority area, which are both privately and publicly owned[2].</td></tr>
<tr><td>Area of Habitat Types Present (ha) and Percent of Each Habitat Type</td><td>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&FR AOC)[3]. Habitat types within Dead Horse Bay 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 167.76 ha of natural habitat in Dead Horse Bay.
<table>
<tr><th>Habitat Type</th><th>Area (ha)</th><th>Percent</th></tr>
<tr><td>Emergent Marsh (High Energy Coastal)</td><td>5.19</td><td>3.10</td></tr>
<tr><td>Green Bay Open Water</td><td>135.64</td><td>80.86</td></tr>
<tr><td>Hardwood Swamp</td><td>0.03</td><td>0.02</td></tr>
<tr><td>Submergent Marsh</td><td>26.90</td><td>16.03</td></tr>
</table>
<i>Disclaimer! 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 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.</i></td></tr>
<tr><td>General Description</td><td>Dead Horse Bay is a part of Green Bay's west shore wetland complex and has been called the "armpit" of Longtail Point being sandwiched in between the west shore and Longtail Point. It largely consists of open water as well as one of the largest and highest quality submergent marshes in the entire LGB&FR AOC, which includes a few small pockets of wild celery (<i>Vallisneria americana</i>) along this priority area's eastern border adjacent to Longtail Point. The Longtail Point peninsula offers protection from wave action to the Dead Horse Bay-west shore wetland complex, which promotes growing conditions for aquatic and submergent plants. The amount and types of habitats may vary depending on lake levels within this rather dynamic Great Lakes coastal system. The effects of lake levels on the amount of emergent and submergent marsh and open water can be seen in aerial imagery from 1938, 1960, and 2014 in comparison to the extremely high lake levels in the 1970s (aerial image from 1978) on the Brown County Online GIS Portal[2]. Rafts of over 20 migratory waterfowl species have been reported within Dead Horse Bay in 2016 and 2017 within the open water and submergent marsh, including American Coot (<i>Fulica americana</i>), scaup, Common Goldeneye</td></tr>
</table>

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[1] File "AOC_PriorityAreas.v09_20171212.shp"

[2] Brown County Online GIS Portal: https://browncounty.maps.arcgis.com/apps/webappviewer/index.html?id=61fba3fd419045e48aa6ba759838387c

[3] LGB&FR AOC 2015 habitat field mapping effort

	(*Bucephala clangula*), Gadwall (*Anas strepera*), teal, mergansers, and more[4], though it is already known as an important migratory waterfowl stopover site[5]. Canvasbacks especially used Dead Horse Bay[6]. Some of these ducks feed on aquatic plant seeds while others forage on zebra mussels (*Dreissena polymorpha*) and aquatic insects, such as worms (subclass Oligochaeta) and chironomids (family Chironomidae)[5]. Dead Horse Bay is popular for fishing and duck hunting. While there are extensive beds of native submerged aquatic vegetation, there is great potential for this site to be enhanced and expanded as well as managed for invasive plant species, such as Eurasian watermilfoil (*Myriophyllum spicatum*). Several research projects have taken place in Dead Horse Bay in recent years, including multiple fish studies (e.g., WDNR, U.S. Fish and Wildlife Service, UW-Green Bay)[7,8], submerged aquatic vegetation survey (UW-Green Bay),[9] migratory waterfowl survey (UW-Green Bay)[10], and invertebrate study (UW-Green Bay)[11].
Special Features	• Contains one of the highest quality submergent marshes in the entire LGB&FR AOC. • Part of the larger west shore wetland complex of lower Green Bay. • Important waterfowl migratory bird stopover site[12] and fish habitat.
Natural Habitat Communities and Significant Plants (ordered in terms of ecological importance and size/amount)	The majority of the Dead Horse Bay priority area is **open water**. Unfortunately, like most of Green Bay, water quality is relatively poor[13]. In fact, on a scale ranging from “excellent” to “highly degraded,” waters near Longtail Point have been classified as “very degraded[13].” Poor water quality, which in this case is largely due to high nutrient loadings from non-point source runoff from agricultural and developed lands, can negatively affect which aquatic and submergent plants are able to thrive. Water levels can also affect which plants colonize areas like Dead Horse Bay. Yet, despite lower Green Bay’s poor water quality, Dead Horse Bay contains one of the highest quality **submergent marshes** in the entire LGB&FR AOC. The most extensive beds of submerged aquatic vegetation are found along the northeastern edge of the west shore, western edge of Longtail Point, and in the northernmost portion of the “armpit” of Longtail Point. Native plants include: • Wild celery (*Vallisneria americana*) • Bladderwort (*Utricularia vulgaris*) • Coontail (*Ceratophyllum demersum*) • Turion duckweed (*Lemna turionifera*) • Slender riccia (*Riccia fluitans*, a thallose liverwort) • Forked duckweed (*Lemna trisulca*) • Sago pondweed (*Stuckenia pectinata*) • Great duckweed (*Spirodela polyrrhiza*) • Turion duckweed (*Lemna turionifera*) • Sessile-fruited arrowhead (*Sagittaria rigida*) • Bull-head pond-lily (*Nuphar variegata*) • Nodding water-nymph (*Najas flexilis*)

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[4] LGB&FR AOC comprehensive biota database: file “AOCBiota_DB_ShareableVersion_20171213.accdb”

[5] Vicky Harris 1998 master’s thesis

[6] Personal communication with Thomas Erdman on 13 January 2016

[7] Disterhaft 2013 Master’s Thesis entitled “Changes in fish assemblages of Lake Michigan's Green Bay following the introduction of Dreissenid mussels and round goby (*Neogobius melanostomus*) during 1980-2010”

[8] UW-Green Bay Aquatic Ecology and Fisheries Lab fish project on nearshore-wetland habitat led by Dr. Patrick Forsythe and Dr. Christopher Houghton; surveys from 2014 and 2015.

[9] AOC Submergent Aquatic Vegetation Surveys led by Dr. James Horn and Dr. Amy Wolf, 2017

[10] AOC Migratory Waterfowl Surveys by Tom Prestby, 2016-2017

[11] Schneider & Sager 2007: “Structure & ordination of epiphytic invertebrate communities of four coastal wetlands in Green Bay, Lake Michigan”

[12] Epstein et al. 2002: “A data compilation and assessment of coastal wetlands of Wisconsin’s Great Lakes”

[13] Chow-Fraser 2006: “Development of the wetland Water Quality Index for assessing the quality of Great Lakes coastal wetlands”

	Along the eastern edge of the west shore and western edge of Longtail Point, there is also **emergent high energy marsh**. Although hybrid cattail (*Typha* × *glauca*) and common reed (*Phragmites australis*; hereafter referred to as "*Phragmites*") dominate these marshes, they also harbor significant populations of river bulrush (*Bolboschoenus fluviatilis*) and floating-leaved bur-reed (*Sparganium fluctuans*).
Significant Animals	**Birds**: • >200 bird species have been reported using the west shore of Green Bay, though Dead Horse Bay provides important stopover and post-breeding season habitat for migratory waterfowl and waterbirds, including[4]: ○ American Coot (*Fulica americana*) ○ Greater Scaup (*Aythya marila*) ○ Lesser Scaup (*Aythya affinis*), state special concern species, listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern, and regional priority species from the North American Waterfowl Management Plan ○ Common Goldeneye (*Bucephala clangula*), state special concern species ○ Gadwall (*Anas strepera*) ○ Blue-winged Teal (*Anas discors*), a state special concern species and listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern ○ Green-winged Teal (*Anas carolinensis*) ○ Hooded Merganser (*Lophodytes cucullatus*), a regional priority species from the North American Waterfowl Management Plan ○ Common Merganser (*Mergus merganser*) ○ Pied-billed Grebe (*Podilymbus podiceps*), listed on the Upper Mississippi River/Great Lakes Waterbird Conservation Plan ○ Black Tern (*Chlidonias niger*), state endangered, federally listed species of concern, listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern, and listed on the Upper Mississippi River/Great Lakes Waterbird Conservation Plan ○ Forster's Tern (*Sterna forsteri*), state endangered and listed as a Wisconsin Wildlife Action Plan Species of Greatest Concern • Many species are known to breed within the emergent marshes of the western edge of Longtail Point and eastern edge of the west shore[14]: ○ Forster's Tern, Marsh Wren (*Cistothorus palustris*), Red-winged Blackbird (*Agelaius phoeniceus*), American Coot, Common Gallinule (*Gallinula galeata*), Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*), and others **Fish**: • Although >80 fish species have been recorded in the pelagic zone of the lower bay, some of which may use Dead Horse Bay. Species that use the bay, include[4]: ○ 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): redside dace (*Clinostomus elongatus*) and lake sturgeon (*Acipenser fulvescens*) ○ Northern pike (*Esox lucius*) traverse through Dead Horse Bay to reach west shore wetlands for spawning

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[14] Wisconsin Breeding Bird Atlas II Project (2015-2019): http://ebird.org/ebird/atlaswi/block/4408758NW?atlasPeriod=EBIRD_ATL_WI_2015& rank=mrec&hs_sortBy=category&hs_o=desc (as of 19 Oct 2016) and http://ebird.org/ebird/atlaswi/block/4408851NE?atlasPeriod=EBIRD_ATL_WI_2015&rank=mrec&hs_sortBy=category&hs_o=desc (as of 19 Oct 2016)

	Mammals: • Although ~50 mammal species are known to or are expected to occur along the west shore (as noted in Roznik 1979)[15], only a few likely use the emergent and submergent marshes of Dead Horse Bay, including muskrat (*Ondatra zibethicus*), North American river otter (*Lontra canadensis*), and American mink (*Neovison vison*)[16,17]. **Mollusks**: • Within the pelagic zone of the lower bay, the following have been recorded: o Freshwater clams: fingernail claim (*Sphaerium* sp.), pea clam (*Pisidium* sp.) o Three snails: mud bithynia (*Bithynia tentaculata*), river snail species (*Campeloma* sp.), and valve species (*Valvata* sp.) **Arthropods**: • Several species have been recorded in the pelagic zone of the lower bay in the 1990s, including: o Long-horn caddisfly (*Oecetis* sp.)[4] o Buzzer midge (*Chironomus plumosus*)[4] o Green midge (*Tanytarsus* sp.)[4] o Riffle beetle species (*Ordobrevia* sp.) from 2007[4] o Non-biting midges (*Polypedilum* sp., *Paratanytarsus* sp., *Parachironomus* sp., and *Parakiefferiella* sp.) from 1995[11] **Annelids**: • Aquatic oligochaete worms have been recorded in the pelagic zone of the lower bay in the early 1990s, including[4]: o *Aulodrilus americanus* o *Dero digitate* o *Nais pardalis* o *Potamothrix moldaviensis* o *Nais communis*
Habitat Quality	Overall, the ecological quality of Dead Horse Bay is relatively low due to poor water quality and the presence of invasive plant species in the submergent and emergent marshes. That being said, there are pockets of native submerged aquatic plants, which provide habitat for fish, waterfowl, and aquatic invertebrates.
Significant Invasive Species Issues	**Invasive Plant Species**: Each of these species outcompetes and crowds out native plants[3,9]: • Eurasian water-milfoil (*Myriophyllum spicatum*) o Found within the submergent marsh • Common reed (*Phragmites australis*) o Some *Phragmites* occurs along the edges of the Dead Horse Bay priority area along the west shore and Longtail Point within the emergent marsh; some management has occurred in recent years in open areas (2011-12, 2015-16). • Hybrid cattail (*Typha* × *glauca*) o Some hybrid cattail occurs along the edges of the Dead Horse Bay priority area along the west shore and Longtail Point within the emergent marsh; management unknown.

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[15] Green Bay West Shores Master Plan Concept Element 1979 by Roznik et al.

[16] Wisconsin Department of Natural Resources Technical Report PUB-LF-073.

[17] Wisconsin Department of Natural Resources 2015 muskrat house survey; noted in file “AOC_ProjectCatalogue_20160922.xlsx”

	Invasive Animal Species: • *Fish*[4] o Alewife (*Alosa pseudoharengus*)[18] ▪ Poses a threat to native fish species by consuming zooplankton and disturbing the natural food web; not currently being managed o Common carp (*Cyprinus carpio*)[19] ▪ Destroy vegetation by uprooting plants and increasing cloudiness of water; not currently being managed o Rainbow smelt (*Osmerus mordax*)[20] ▪ Negatively affect uncommon to rare native fish species; not currently being managed o Round goby (*Neogobius melanostomus*)[21] ▪ Prey on small native fish and eggs (e.g., darters) and outcompete similarly sized native fish; not currently being managed o White perch (*Morone americana*)[22] ▪ Prey on native fish eggs, such as walleye; not currently being managed • *Freshwater mussels* o Zebra mussel (*Dreissena polymorpha*)[23] ▪ Poses threat to native freshwater mussels; not currently being managed
Management and Restoration Recommendations	• Control introduced plant species (e.g., Eurasian watermilfoil) and maintain extensive and high quality submerged aquatic vegetation with native plants. • Determine substrate needs for target plant species and then enhance and restore substrate condition. • Protect, maintain, and expand submerged aquatic vegetation biodiversity hotspots. • Implement Upper Fox, Wolf, and Lower Fox basin's total maximum daily loads (TMDL) to improve water quality. • Promote best management practices and innovative nutrient management measures in Fox River watershed. • Develop or restore important fish spawning and nursery habitats, such as rocky reefs, gravel, cobble, woody debris, and sandy areas for shoreline fish. • Control invasive plant species (*Phragmites* + hybrid cattail) within the emergent marsh and maintain an appropriate mix of open water native emergent vegetation.
Reference Links and Documents	**Web Links**: • Drone footage of Dead Horse Bay from 2016: https://www.youtube.com/watch?v=Inhn5iZT8-Y

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[18] 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.

[19] 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.

[20] 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.

[21] 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.

[22] 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.

[23] Wisconsin Department of Natural Resources Technical Report PUBL ER-818 2010

	Reference Documents: • 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. • Disterhaft, K. 2013. Changes in fish assemblages of Lake Michigan's Green Bay following the introduction of Dreissenid mussels and round goby (*Neogobius melanostomus*) during 1980-2010. Master's thesis from the University of Wisconsin-Green Bay. • Frieswyk, C.B., C.A. Johnston, and J.B. Zedler. 2007. Identifying and characterizing dominant plants as an indicator of community condition. Journal of Great Lakes Research. 33(3):125-135. ○ Available: http://glei.nrri.umn.edu/default/documents/frieswyk_jglr_2007.pdf • 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. • Mossman, M.J. 1989. Wisconsin Forster's Tern Recovery Plan. Passenger Pigeon 51(2):171-186. http://images.library.wisc.edu/EcoNatRes/EFacs/PassPigeon/ppv51no02/reference/econatres.pp51n02.mmossman.pdf • Schneider, P. and P.E. Sager. 2007. Structure and ordination of epiphytic invertebrate communities of four coastal wetlands in Green Bay, Lake Michigan. Journal of Great Lakes Research 33:342-357. • Wisconsin Department of Natural Resources. 2013. Regional and property analysis: Green Bay Planning Group. Technical Report PUB-LF-073. • Wisconsin Department of Natural Resources. 2014. Green Bay Planning Group Master Plan. Technical Report PUB-LF-075.
Site History (e.g., original vegetation, past conservation projects)	In the early 1630s, Frenchman Jean Nicolet first arrived in lower Green Bay when it was primarily inhabited by Native American tribes[24]. Lower Green Bay consisted of large beds of wild rice (*Zizania* sp.) and wild celery (*Vallisneria americana*), extensive emergent marsh (*Schoenoplectus* spp., cattail), sedge meadows (*Calamagrostis canadensis*), shrub carr (e.g., *Cornus* spp., *Salix* spp.), swamps, and wet conifer forest (black spruce [*Picea mariana*], balsam fir [*Abies balsamea*])[25,26,27,28,29]. Between the late 1600s and 1800s, European fur trade, duck hunting, fishing, logging, shipping, and agriculture were important early industries in lower Green Bay[30,31,32]. In the early 1800s, there were a few small settlements and farms of Europeans and Native Americans in the lower Bay[31].

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

[25] Arthur C. Neville's Map of Historic Sites on Green Bay, Wisconsin 1669-1689. Available: http://s3.amazonaws.com/labaye/data/Bay%20Settle ment%20Map%20WI%20Historical%20Bulletin%201926.pdf (accessed on 24 Oct 2016).

[26] 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).

[27] 1845 Chart of Green Bay. Available http://s3.amazonaws.com/labaye/data/1845%20Chart%20of%20Green%20Bay.pdf (accessed on 24 Oct 2016).

[28] 1820s Fox River Military Road Map to Ft. Crawford. Available: http://s3.amazonaws.com/labaye/data/1820s%20Fox%20River%20Military%20 Road%20Map%20to%20Ft.%20Crawford.pdf (accessed on 24 Oct 2016).

[29] UW-Green Bay personal communication with Thomas Erdman.

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

[31] 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).

[32] 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).

	Prior to the arrival of many invasive plants species in the late 1990s, the emergent marsh at Longtail Point (which likely included the outer edges of Dead Horse Bay) consisted of soft-stem bulrush (*Schoenoplectus tabernaemontani*) and three-square bulrush (*Schoenoplectus pungens*). There also used to be a sedge meadow consisting of blue-joint grass (*Calamagrostis canadensis*) and cattails (*Typha latifolia*), hardwood swamp, and a small amount of shrub carr. From the 1960s through the early 1980s, Forster's Terns regularly nested on floating mats of vegetation at Longtail Point[33]. Today, Dead Horse Bay is a popular location for fishing and duck hunting, but it has also been an important study site for many researchers in recent years, particularly fish research. 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. Fish data that Disterhaft used for her thesis are a part of a long-term fish monitoring effort in the bay of Green Bay led by the WDNR's Tammie Paoli[34]. 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[34]. They plan to estimate the coastal wetland habitat that is used by sport fish species and to build habitat food webs[34]. Two of their seven survey locations are in the LGB&FR AOC, namely Dead Horse Bay and Point Sable[34]. The U.S. Fish and Wildlife Service coordinate an early detection and monitoring program of aquatic invasive species in Lake Michigan, and many of their sampling locations are in the LGB&FR AOC, including along the outer edges of Dead Horse Bay[34]. They survey for ichthyoplankton, carp, macroinvertebrates, and nearshore fishes[34]. UW-Green Bay's Patricia Schneider and Dr. Paul Sager conducted a study in 1995 to better understand epiphytic invertebrate communities in Green Bay coastal wetlands, one of which was in Dead Horse Bay[11]. 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 vegetation beds throughout the LGB&FR AOC and found that Dead Horse Bay has one of the highest quality submergent marshes in the LGB&FR AOC[9]. In 2016-2017 under the guidance of CCB's Dr. Howe, Dr. Wolf, and Erin Giese, Tom Prestby surveyed migratory waterfowl within the LGB&FR AOC, including a sampling location on the west shore roughly facing the center of Dead Horse Bay and Longtail Point[10]. Waterfowl rafts were digitized into ArcGIS by Cody Becker.

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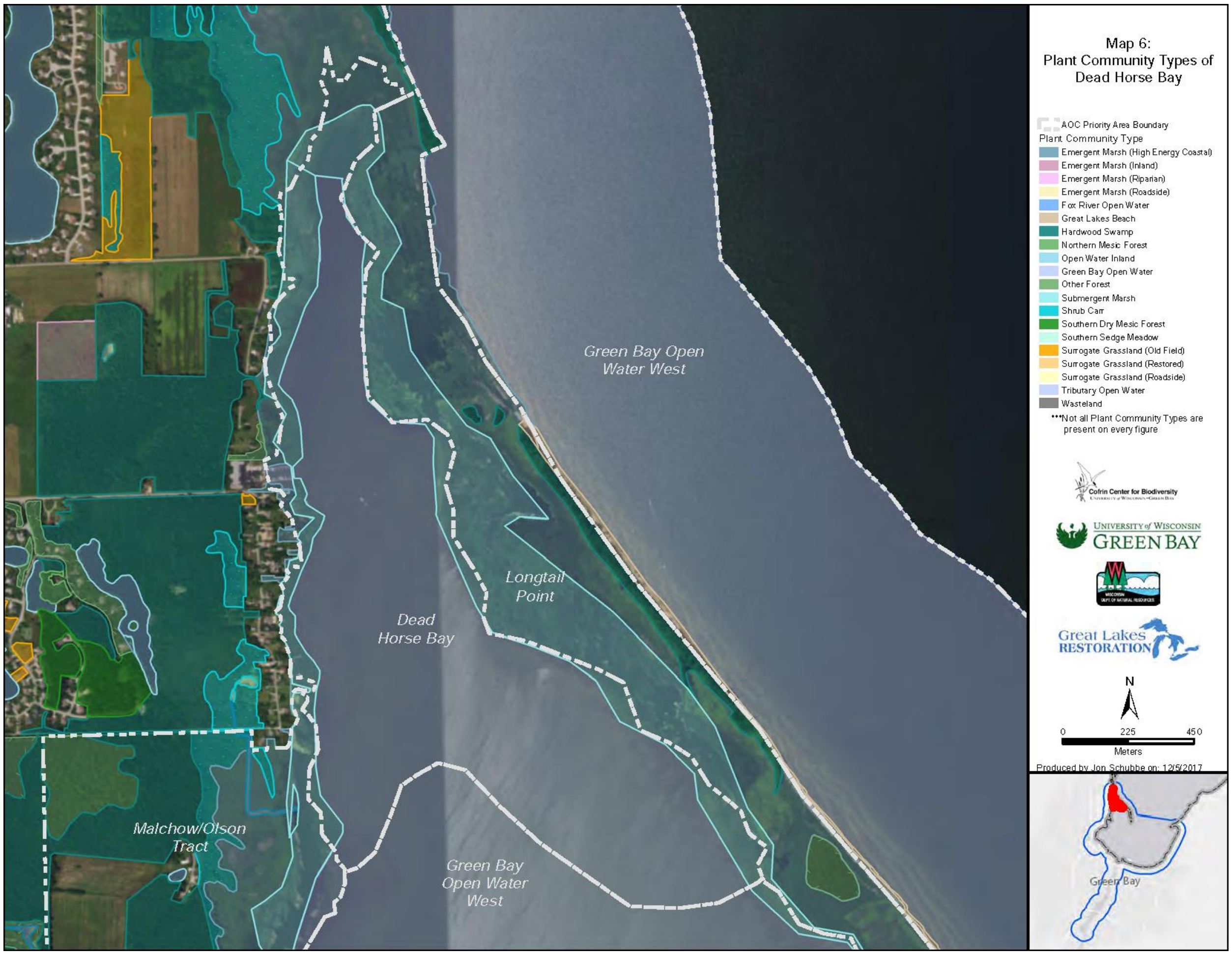
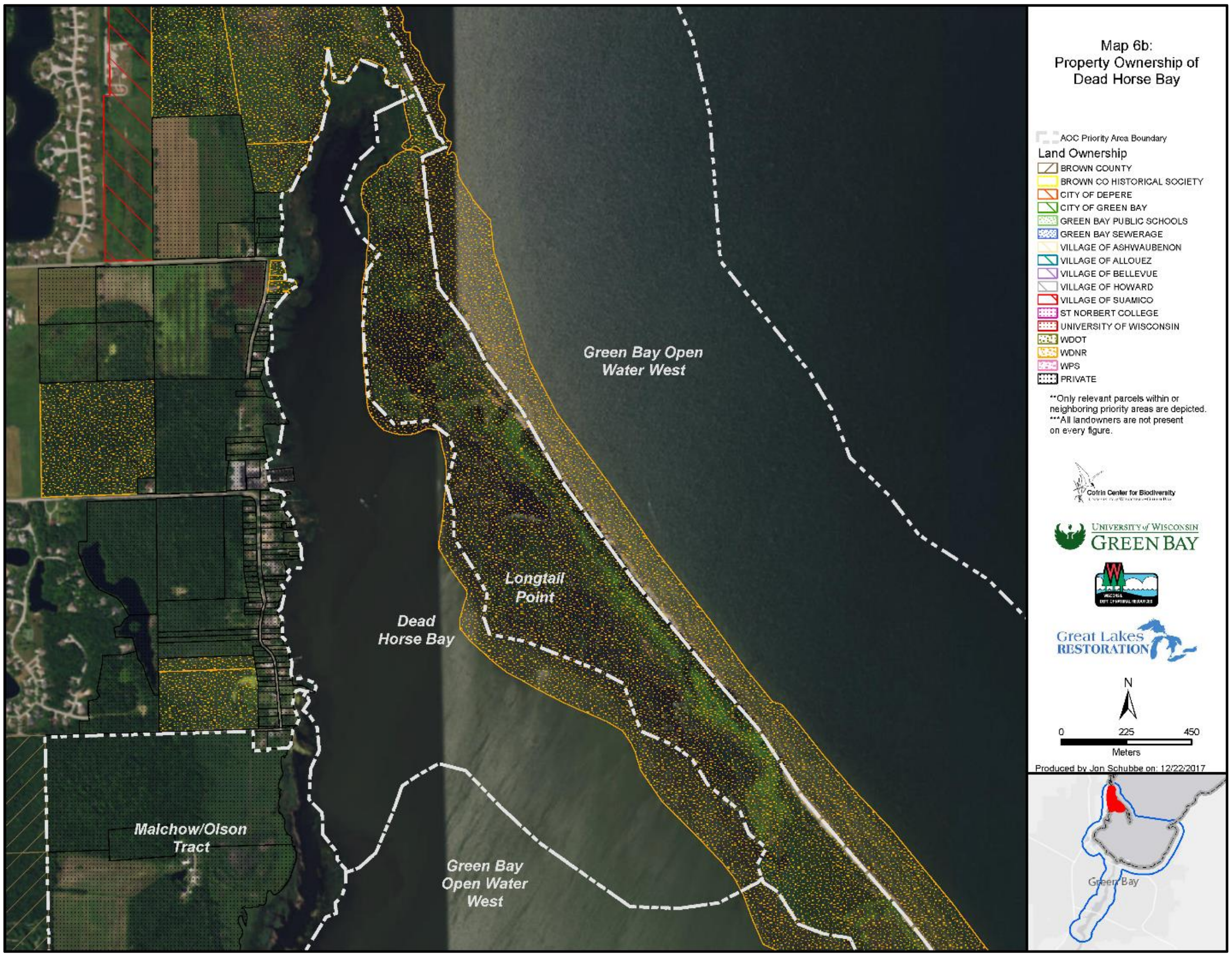
[33] Mossman 1989: Wisconsin's Forster's Tern Recovery Plan: http://images.library.wisc.edu/EcoNatRes/EFacs/PassPigeon/ppv51no02/reference/econatres.pp51n02.mmossman.pdf

[34] Green Bay Fish Working Group Annual Meetings on 20 March 2015, 6 January 2016, and 4 January 2017

Map of Dead Horse Bay's 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.



Land ownership boundaries at Dead Horse Bay. Map made by UW-Green Bay's Jon Schubbe.



Photograph of Dead Horse Bay facing northwest. Photograph taken by Erin Giese on 2 December 2016.

Appendix 10.7: Duck Creek Estuary North

Written by Erin Giese and James Horn

<table>
<tr><td>Location (centroid)</td><td>Lat. 44.570742°, Lon. -88.043562°[1] (NAD 1983, UTM Zone 16N)</td></tr>
<tr><td>Total Area (ha)</td><td>82.49 ha</td></tr>
<tr><td>Area Public Land (ha)</td><td>77.43 ha, land owned by the Wisconsin Department of Natural Resources</td></tr>
<tr><td>Area of Habitat Types Present (ha) and Percent of Each Habitat Type</td><td>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&FR AOC)[2]. Habitat types within Duck Creek Estuary North 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 82.21 ha of natural habitat in Duck Creek Estuary North.
<table>
<tr><th>Habitat Type</th><th>Area (ha)</th><th>Percent</th></tr>
<tr><td>Emergent Marsh (High Energy Coastal)</td><td>35.18</td><td>42.80</td></tr>
<tr><td>Hardwood Swamp</td><td>17.00</td><td>20.68</td></tr>
<tr><td>Shrub Carr</td><td>19.75</td><td>24.03</td></tr>
<tr><td>Submergent Marsh</td><td>10.25</td><td>12.47</td></tr>
<tr><td>Tributary Open Water</td><td>0.02</td><td>0.03</td></tr>
</table>
<i>Disclaimer! 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 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.</i></td></tr>
<tr><td>General Description</td><td>Duck Creek Estuary North is located north of the mouth of Duck Creek alongside Interstate 41 and is a part of the Duck Creek Delta wetland complex. While the priority area has been significantly modified over the years from development, road construction, and agricultural/storm water runoff, it still features a natural hydrologic gradient that grades from submergent/emergent marsh into southern sedge meadow, shrub carr, and hardwood swamp. While Duck Creek flows northeast from roughly 22 km (13.8 mi) inland and empties into the bay of Green Bay, it has been known to reverse course and flow upstream (i.e., southwest) as far as 6.4 km (4 mi) during high water levels and seiche in the bay[12]. It primarily consists of Tedrow loamy fine sand soils and Keowns silt loam[3].

Historically, however, this priority area was a part of a huge wetland complex of submergent and emergent marsh of >200 ha that was protected by a group of barrier islands called the Cat Island Chain, as seen on 1938 aerial imagery from the Brown County Online GIS Portal. This wetland complex provided critical wildlife habitat for fish, birds, invertebrates, and furbearers and offered a protected refugium for native plants, including wild rice (<i>Zizania palustris</i>) and wild celery (<i>Vallisneria americana</i>).</td></tr>
</table>

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[1] File "AOC_PriorityAreas.v09_20171212.shp"

[2] LGB&FR AOC 2015 habitat field mapping effort

[3] Soil Survey Geographic (SSURGO) by the United States Department of Agriculture's Natural Resources Conservation Service. Published Dec 2010. Available: http://uwgb.maps.arcgis.com/home/item.html?id=204d94c9b1374de9a21574c9efa31164; accessed 15 Dec 2017.

	Unfortunately, due to extremely high water levels in the bay, massive storms, and hardened shorelines, these islands largely washed away during the spring of 1973[4,5]. The huge Duck Creek Delta wetland complex vanished because the islands no longer provided the much needed wave/storm protection[4,5]. In May of 2013, these barrier islands were reconstructed along a causeway with artificial islands called "cells" (project called the Cat Island Wave Barrier), where shipping canal dredge material will be placed over the next 20-30 years. This project was originally initiated by a local group of dedicated conservationists in the 1980s, and the hope is that this once extensive submergent and emergent marsh will reform in the coming years given the right conditions and lake levels. Including the Duck Creek Estuary North priority area, the Duck Creek Delta is a heavily studied area in the lower bay. Researchers and managers from the Wisconsin Department of Natural Resources (WDNR), U.S. Fish and Wildlife Service (FWS), UW-Green Bay, and Oneida Tribe have conducted studies on plants, fish, birds, anurans (frogs + toads), spiders, and water quality as well as multiple restoration efforts, including the attempt to re-establish wild rice. Because of the added protection of the Cat Island Wave Barrier and pockets of relatively good quality habitat, the Duck Creek Estuary North priority area has great potential to be improved and restored and should be considered a high priority restoration site.
Special Features	• Offers a landscape of submergent and emergent marsh that grades into southern sedge meadow, shrub carr, and hardwood swamp; this landscape describes the historical mosaic originally found in lower Green Bay[2,6,7]. • Features a small patch of southern sedge meadow, which is a rare habitat in the LGB&FR AOC and across the state, that is largely dominated by broad-leaved woolly sedge (*Carex pellita*) and common tussock sedge (*Carex stricta*). • Forster's Terns nest on artificial nesting structures in the Duck Creek Delta[8]. • Important habitat for muskrats in the emergent marsh. • Northern border of the mouth of Duck Creek, which forms a bird's-foot delta.
Natural Habitat Communities and Significant Plants (ordered in terms of ecological importance and size/amount)	Despite many anthropogenic modifications, the Duck Creek Estuary North priority still maintains a natural coastal gradient from submergent marsh to emergent marsh, southern sedge meadow, shrub carr, and finally to hardwood swamp. Nearly half of this priority area consists of **emergent marsh**, which is largely dominated by common reed (*Phragmites australis*; hereafter referred to as "*Phragmites*") and hybrid cattail (*Typha* × *glauca*)[2,7,9]. Native plant species are present in this emergent marsh, but mostly confined to its periphery, and constitute c. 2% of the total extent of vegetation coverage. Broad-leaved arrowhead (*Sagittaria latifolia*), arum-leaved arrowhead (*Sagittaria cuneata*), and northern water-plantain (*Alisma triviale*) were aspect dominants in this marginal band of mostly native species during the 2016 surveys of LGB&FR AOC biodiversity hotspots. The **shrub carr** is dominated by meadow willow (*Salix petiolaris*), sandbar willow (*Salix interior*), red-osier dogwood (*Cornus sericea*), and eastern meadowsweet (*Spiraea alba*) with an herbaceous layer of sedges (*Carex* spp.), marsh bluegrass (*Poa palustris*), and goldenrod (*Solidago* spp.)[2,7,9]. Along the northern edge of this priority area, the **hardwood swamp** has a canopy of green ash (*Fraxinus pennsylvanica*), cottonwood (*Populus deltoides*), trembling aspen

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[4] Brown County Port and Resource Recovery Cat Island document: https://static1.squarespace.com/static/56ec0372859fd0e272858772/t/574db48fab48de7bc23597a0/1464710289702/2014+Cat+Island+Abstract+Spring.pdf

[5] Frieswyk and Zedler 2007

[6] Bertrand et al. 1976: The Green Bay Watershed Past/Present/Future

[7] LGB&FR AOC plant biodiversity hotspots field effort

[8] LGB&FR AOC Stakeholder Meeting on 23 June 2015 per Gary Van Vreede

[9] LGB&FR AOC submerged aquatic vegetation mapping led by Dr. Amy Wolf and Dr. James Horn

	(*Populus tremuloides*), paper birch (*Betula papyrifera*), and box elder (*Acer negundo*) and an understory of gray dogwood (*Cornus foemina*), cherry (*Prunus* sp.), nannyberry (*Viburnum lentago*), sensitive fern (*Onoclea sensibilis*), goldenrod, and sedges (*Carex* spp.). Parts of the forest's understory are heavily dominated by glossy buckthorn (*Frangula alnus*) [2,7,9]. Along the eastern edge is a narrow band of **submergent marsh** that consists of a few natives[2,7,9]: • Coontail (*Ceratophyllum demersum*), common • Forked duckweed (*Lemna trisulca*), moderately common • Slender riccia (*Riccia fluitans*, a thallose liverwort), moderately common • Sago pondweed (*Stuckenia pectinata*), moderately common • Common bladderwort (*Utricularia vulgaris*), moderately common • Wild celery (*Vallisneria americana*), moderately common Patches of submergent marsh dominated by fragrant water-lily (*Nymphaea odorata*) are conspicuous along the north bank of the north Duck Creek inlet, at the southern edge of this priority area. Eurasian water-milfoil (*Myriophyllum spicatum*) is also mixed in with natives and is moderately common in the submergent marsh along the shore of Peats Lake[2,7,9]. There is also a small patch of disturbed **southern sedge meadow** that is largely dominated by native plants including broad-leaved woolly sedge (*Carex pellita*) and common tussock sedge (*Carex stricta*). This parcel is one of the most species-rich areas in the LGB&FR AOC for vascular plants with almost 60 native species documented in the 2016 plant surveys. Reed canary grass (*Phalaris arundinacea*) also occurs here, though it is not a dominant. Dominant and significant natives include[2,7,9]: • Bebb's sedge (*Carex bebbii*), moderately common • Giant goldenrod (*Solidago gigantea*), moderately common • Marsh bluegrass (*Poa palustris*), moderately common • Common goldenrod (*Solidago canadensis*), moderately common • Water-parsnip (*Sium suave*), rare • Eastern meadowsweet (*Spiraea alba*), rare • Common lake sedge (*Carex lacustris*), rare • Fox sedge (*Carex vulpinoidea*), rare • Loesel's twayblade orchid (*Liparis loeselii*), rare • Common false foxglove (*Agalinis tenuifolia*), rare • Tufted loosestrife (*Lysimachia thyrsiflora*), rare • Marsh fern (*Thelypteris palustris*), rare However, this sedge meadow was not digitized or mapped during the 2015 LGB&FR AOC field effort because it is small and forms a mosaic with adjacent shrub carr, which is why it is not delineated in the habitat map below. Its general location is identified with a star symbol.
Significant Animals	**Birds**: • Over 200 bird species have been recorded along parts of the west shore, including[10] o Four state endangered species (Caspian Tern [*Hydroprogne caspia*], Common Tern [*Sterna hirundo*], Forster's Tern [*Sterna forsteri*], and Peregrine Falcon [*Falco peregrinus*]) o Four state threatened species (Great Egret [*Ardea alba*], Acadian Flycatcher [*Empidonax virescens*], Yellow-crowned Night-Heron (*Nyctanassa violacea*), and Cerulean Warbler [*Setophaga cerulea*])

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[10] LGB&FR AOC Biota Database: file "AOCBiota_DB_ShareableVersion_20171213.accdb"

  - Forty-one Wisconsin Wildlife Action Plan Species of Greatest Concern (e.g., Brown Thrasher [*Toxostoma rufum*], Canada Warbler [*Cardellina canadensis*])
  - Forty-two state special concern species (e.g., Yellow-billed Cuckoo [*Coccyzus americanus*], Bald Eagle [*Haliaeetus leucocephalus*], Black-throated Blue Warbler [*Setophaga caerulescens*], Purple Martin [*Progne subis*])
  - Seven International Union for Conservation of Nature-listed species as vulnerable (e.g., Rusty Blackbird [*Euphagus carolinus*]) or near threatened (e.g., Golden-winged Warbler [*Vermivora chrysoptera*], Red-headed Woodpecker [*Melanerpes erythrocephalus*])
  - Migratory waterfowl and gulls, including scaup, use the waters off the shores of Duck Creek Estuary North
- Despite the emergent marsh's lack of native plant diversity, it provides critical nesting habitat for many marsh- (and sometimes secretive) breeding birds, although the presence of some of these species depends on lake levels[11]:
  - Forster's Tern
  - American Coot (*Fulica americana*)
  - Pied-billed Grebe (*Podilymbus podiceps*)
  - Sora (*Porzana carolina*)
  - Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*)
  - Red-winged Blackbird (*Agelaius phoeniceus*)
- Cliff Swallows (*Petrochelidon pyrrhonota*) and Barn Swallows (*Hirundo rustica*) nest under the Interstate 41 bridge on the western edge of this priority area's border[11].

Fish:

- Although >80 fish species have been recorded in the pelagic zone of the lower bay, only some of which may use areas near the Duck Creek Delta including[10]:
  - 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): redside dace (*Clinostomus elongatus*) and lake sturgeon (*Acipenser fulvescens*)
  - Northern pike (*Esox lucius*)

Mammals:

- Although ~50 mammal species are known to or are expected to occur along the west shore (as noted in Roznik 1979)[12], only a few likely use the emergent and submergent marshes of the Duck Creek Delta, including muskrat (*Ondatra zibethicus*), North American river otter (*Lontra canadensis*), and American mink (*Neovison vison*)[13,14].
  - In fact, when looking at Google Earth's 2017 aerial imagery, dozens of muskrat lodges are visible along the eastern edge of this priority area in the emergent marsh.

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[11] WI Breeding Bird Atlas II Project – data available here: http://ebird.org/ebird/atlaswi/explore

[12] Green Bay West Shores Master Plan Concept Element 1979 by Roznik et al.

[13] Wisconsin Department of Natural Resources Technical Report PUB-LF-073.

[14] Wisconsin Department of Natural Resources 2015 muskrat house survey

	Anurans: • Spring peeper (*Pseudacris crucifer*) and American toad (*Bufo americanus*) have been recorded calling within the emergent marsh based on 2012 and 2017 surveys[15]. Other anurans may use this marsh, too, such as eastern gray treefrog (*Hyla versicolor*). **Mollusks**: • Within the pelagic zone of the lower bay, the following has been recorded: o Freshwater clams: fingernail claim (*Sphaerium* sp.), pea clam (*Pisidium* sp.) o Three snails: mud bithynia (*Bithynia tentaculata*), river snail species (*Campeloma* sp.), and valve species (*Valvata* sp.) **Arthropods**: • Several species have been recorded in the pelagic zone of the lower bay in the 1990s, including: o Long-horn caddisfly (*Oecetis* sp.)[10] o Buzzer midge (*Chironomus plumosus*)[10] o Green midge (*Tanytarsus* sp.)[10] o Riffle beetle species (*Ordobrevia* sp.) from 2007[10] o Non-biting midges (*Polypedilum* sp., *Paratanytarsus* sp., *Parachironomus* sp., and *Parakiefferiella* sp.) from 1995[16] • Several different spider species, including[17]: o *Clubiona pallidula* o *Larinioides cornutus* o *Leiobunum flavum* o *Pachygnatha dorothea* **Annelids**: • Aquatic oligochaete worms have been recorded in the pelagic zone of the lower bay in the early 1990s, including[10]: o *Aulodrilus americanus* o *Dero digitata* o *Nais pardalis* o *Nais communis*
Habitat Quality	Overall, the ecological quality of Duck Creek Estuary North's habitats is mediocre though parts of this priority area are in fairly good condition. For example, there is a nice mix of native plants in the submergent marsh and southern sedge meadow, in which invasive plants are not the dominants. There is great potential for this priority area to be improved and restored, particularly the sedge meadow which could be expanded.
Significant Invasive Species Issues	**Invasive Plant Species**: Each of these species outcompetes and crowds out native plants[2,7,9]: • Eurasian water-milfoil (*Myriophyllum spicatum*) o Found within the submergent marsh mixed in with native submergents • Common reed (*Phragmites australis*) o *Phragmites* is found closest to the road mixed in with hybrid cattail. Some management has occurred in recent years in open areas (2011-2012) • Hybrid cattail (*Typha* × *glauca*) o It is mixed in with *Phragmites* along the road but dominates >90% of the emergent marsh • Glossy buckthorn (*Frangula alnus*)

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[15] Great Lakes Coastal Wetland Monitoring Program anuran surveys, 2012 and 2017; per Erin Giese

[16] Schneider & Sager 2007: "Structure & ordination of epiphytic invertebrate communities of four coastal wetlands in Green Bay, Lake Michigan"

[17] Draney and Jaskula 2004: Araneae and Opiliones from *Typha* spp. and *Phragmites australis* stands of Green Bay

    - Commonly found throughout most of the hardwood swamp
- Reed canary grass (*Phalaris arundinacea*)
    - Found in the small patch of southern sedge meadow, though it is not a dominant
- Honeysuckle (*Lonicera* × *bella*)
    - Rare in hardwood swamp understory
- Bittersweet nightshade (*Solanum dulcamara*)
    - Rare in hardwood swamp understory
- European fireweed (*Epilobium hirsutum*)
    - Rare in sedge meadow

Invasive Animal Species:

- *Birds*[10]
    - European Starling (*Sturnus vulgaris*)
        - Poses some threat to native species, particularly cavity nesters (e.g., Tree Swallow), by outcompeting them and occupying potential nest sites; not currently being managed.
    - It is possible that House Sparrows (*Passer domesticus*) occur along the road/interstate, potentially outcompeting Cliff and Barn Swallows for nests since House Sparrows are known to use old swallow nests; not currently being managed.

- *Fish*[10]
    - Alewife (*Alosa pseudoharengus*)[18]
        - Poses a threat to native fish species by consuming zooplankton and disturbing the natural food web; not currently being managed
    - Common carp (*Cyprinus carpio*)[19]
        - Destroy vegetation by uprooting plants and increasing cloudiness of water; not currently being managed
    - Rainbow smelt (*Osmerus mordax*)[20]
        - Negatively affect uncommon to rare native fish species; not currently being managed
    - Round goby (*Neogobius melanostomus*)[21]
        - Prey on small native fish and eggs (e.g., darters) and outcompete similarly sized native fish; not currently being managed
    - White perch (*Morone americana*)[22]
        - Prey on native fish eggs, such as walleye; not currently being managed

- *Freshwater mussels*[10]
    - Zebra mussel (*Dreissena polymorpha*)[23]

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[18] 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.

[19] 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.

[20] 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.

[21] 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.

[22] 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.

[23] Wisconsin Department of Natural Resources Technical Report PUBL ER-818 2010: file "WDNR2010_RapidEcologicalAssmtForGBWestShores WildlifeArea.pdf"

	▪ Poses threat to native freshwater mussels; not currently being managed • *Annelids*[10] ○ A tubificid worm (*Potamothrix moldaviensis*)
Management and Restoration Recommendations	• Control the spread of the *Phragmites* and invasive cattail and maintain extensive, high quality native plants in the emergent marsh (high energy coastal). • Expand existing southern sedge meadow remnants, control invasive plants, restore hydrology if needed, and promote the spread of native plants. • Control introduced plant species (e.g., Eurasian watermilfoil) and maintain extensive and high quality submerged aquatic vegetation (SAV) with native plants at Duck Creek. • Control woody invasive plants (e.g., glossy buckthorn) in the hardwood swamp. • Continue investigating the re-establishment of wild rice and wild celery near the mouth of Duck Creek. • Place woody debris for fish habitat. • Continue providing artificial nest structures for Forster's Terns. • Construct nest structures for nesting Black Terns. • Promote best management practices and innovative nutrient management measures in the Fox River watershed.
Reference Links and Documents	**Web Links**: • Dam removal on Duck Creek with Oneida Tribe, Wisconsin Department of Natural Resources, Brown County, U.S. Fish and Wildlife Service, and Oneida Golf and Country Club: https://greatlakesinform.org/projects-and-progress/498 • Wild rice seeding in the lower bay of Green Bay, led by Dr. Amy Carrozzino-Lyon: http://www.ducks.org/conservation/glar/wisconsin/green-bay-partnership-to-improve-wildlife-habit-water-quality • History of the Village of Howard as it pertains to the Duck Creek area: http://www.villageofhoward.com/245/History • Nonpoint Source Control Plan for the Duck, Apple, and Ashwaubenon Creeks Priority Watershed Project: http://dnr.wi.gov/topic/nonpoint/documents/9kep/Duck_Apple_Ashwaubenon_Creeks-Plan.pdf **Reference Documents**: • Bosley, T.R. 1978. Loss of wetlands on the west shore of Green Bay. Wisconsin Academy of Sciences, Arts, and Letters 66:235-245. • 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. • Dorney, J.R. 1975 The vegetation pattern around Green Bay in the 1840s as related to geology, soils, and land use by Indians with a detailed look at the Townships of Scott, Green Bay, and Suamico. Book available through the UW-Green Bay Cofrin Library Archives and Area Research Center. • Frieswyk, C.B., C.A. Johnston, and J.B. Zedler. 2007. Identifying and characterizing dominant plants as an indicator of community condition. Journal of Great Lakes Research. 33(3):125-135. ○ Available: http://glei.nrri.umn.edu/default/documents/frieswyk_jglr_2007.pdf • 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. • Mossman, M.J. 1989. Wisconsin Forster's Tern Recovery Plan. Passenger Pigeon 51(2):171-186.

	http://images.library.wisc.edu/EcoNatRes/EFacs/PassPigeon/ppv51no02/reference/econatres.pp51n02.mmossman.pdf - Wisconsin Department of Natural Resources. 2013. Regional and property analysis: Green Bay Planning Group. Technical Report PUB-LF-073. - Wisconsin Department of Natural Resources. 2014. Green Bay Planning Group Master Plan. Technical Report PUB-LF-075.
Site History (e.g., original vegetation, past conservation projects)	In the early 1630s, Frenchman Jean Nicolet first arrived in lower Green Bay when it was primarily inhabited by Native American tribes[24]. Lower Green Bay consisted of large beds of wild rice (*Zizania* sp.) and wild celery (*Vallisneria americana*), extensive emergent marsh (*Schoenoplectus* spp., cattail [*Typha* sp.]), sedge meadows (*Calamagrostis canadensis*), shrub carr (e.g., *Cornus* spp., *Salix* spp.), swamps, and wet conifer forest (black spruce [*Picea mariana*], balsam fir [*Abies balsamea*])[25,26,27,28,29]. Between the late 1600s and 1800s, European fur trade, duck hunting, fishing, logging, shipping, and agriculture were important early industries in lower Green Bay[30,31,32]. In the early 1800s, there were a few small settlements and farms of Europeans and Native Americans in the lower Bay[31]. In fact, there were a few Native American campsites near the mouth of Duck Creek with villages further upstream[33]. Historical vegetation of the Duck Creek Delta was described as consisting of a grassy marsh and meadow with swamp forest of tamarack and black ash[33,34]. This site was an important migratory stopover site for waterfowl, especially for Tundra Swans[35]. Early European settlers founded the Town of Howard in 1835 and settled along Duck Creek. Residents worked in the timber, farming, quarry, and mail carrier businesses[36]. According to Roznik (1979), even in the 1930s, huge numbers of migratory waterfowl using this area rivaled historic levels. In the late 1960s and early 1970s, vegetation associated with Atkinson's Marsh, which is a part of the Duck Creek Delta complex, consisted of bulrush (*Scirpus* spp.), spike-rush (*Eleocharis* spp.), cattail, sedges (*Carex* spp.), grasses (*Calamagrostis* spp.), and organic mats of vegetation[37]. Panfish, carp, bullhead, yellow perch, and northern pike were found in large numbers in Duck Creek in the 1970s, especially yellow perch[12,35]. In fact, there used to be a carp fishing crew based out of the Duck Creek area[37].

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

[25] Arthur C. Neville's Map of Historic Sites on Green Bay, Wisconsin 1669-1689. Available: http://s3.amazonaws.com/labaye/data/Bay%20Settle ment%20Map%20WI%20Historical%20Bulletin%201926.pdf (accessed on 24 Oct 2016).

[26] 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).

[27] 1845 Chart of Green Bay. Available http://s3.amazonaws.com/labaye/data/1845%20Chart%20of%20Green%20Bay.pdf (accessed on 24 Oct 2016).

[28] 1820s Fox River Military Road Map to Ft. Crawford. Available: http://s3.amazonaws.com/labaye/data/1820s%20Fox%20River%20Military%20 Road%20Map%20to%20Ft.%20Crawford.pdf (accessed on 24 Oct 2016).

[29] UW-Green Bay personal communication with Thomas Erdman.

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

[31] 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).

[32] 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).

[33] The vegetation pattern around Green Bay in the 1840s as related to geology, soils, and land use by Indians with a detailed look at the Townships of Scott, Green Bay, and Suamico by John Dorney, 1975

[34] Wisconsin Public Land Survey System (1834) from file "PLSS_SurveyData.shp"

[35] Fish and Wildlife Resources of the Great Lakes Coastal Wetlands within the United States, Volume 5: Lake Michigan, Part 3, October 1981

[36] History of the Village of Howard: http://www.villageofhoward.com/245/History (accessed on 16 Dec 2017)

[37] Howlett, Jr. 1974: The rooted vegetation of west Green Bay with reference to environmental change

	This priority area was also a part of a huge wetland complex of submergent and emergent marsh of >200 ha that was protected by a group of barrier islands called the Cat Island Chain, as seen on 1938 aerial imagery from the Brown County Online GIS Portal. Unfortunately, between 1834 and 1975, 3.64 km^2 (2.26 mi^2) out of 4.07 km^2 (2.53 mi^2) of marsh were lost between the Fox River and Duck Creek due to the construction of Highways 41 and 141, a landfill, and dredge spoil deposition[38]. Between Duck Creek and the Little Suamico River, 1.92 km^2 (1.19 mi^2) out of 2.56 km^2 (1.59 mi^2) of wetland were also lost[38]. The destruction of these wetlands by the 1970s roughly coincided with extremely high water levels in the bay and massive storms in the spring of 1973[39,40]. The Cat Island Chain of islands washed away, which ultimately caused the once extensive Duck Creek Delta wetland complex to vanish because the islands no longer provided the much needed wave/storm protection[4,5], though a small part of the original Duck Creek Delta wetland complex still exists 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[41]. It took decades for that idea to materialize and became a reality, but it finally happened[41]. By May of 2013, these barrier islands were reconstructed along a causeway with artificial islands called "cells" (project site called the Cat Island Wave Barrier), where shipping canal dredge material will be placed over the next 20-30 years. The hope is that the once extensive Duck Creek Delta submergent and emergent marsh will reform in the coming years given the right conditions and lake levels. Because of the added protection of the Cat Island Wave Barrier and pockets of relatively good quality habitat, the Duck Creek Estuary North priority area has great potential to be improved and restored and should be considered a high priority restoration site. Including the Duck Creek Estuary North priority area, the Duck Creek Delta has recently been a heavily studied area in the lower bay: • In 2002, Dr. Michael Draney and UW-Green Bay student, Jeanette Jaskula, conducted a spider/harvestman study in Duck Creek and other neighboring marshes in 2002 with sample sites in cattail and *Phragmites* marshes[17]. • The U.S. Fish and Wildlife Service (FWS) coordinate an early detection and monitoring program of aquatic invasive species in Lake Michigan, and many of their sampling locations are in the LGB&FR AOC, including along the southern border of the Duck Creek Estuary North priority area[42]. They survey for ichthyoplankton, carp, macroinvertebrates, and nearshore fishes[42]. • In 2011-2012, the WDNR applied herbicide primarily targeting *Phragmites* throughout the emergent high energy marsh[43]. • The Oneida Tribe recently led a dam removal project in collaboration with the WDNR, Brown County, FWS, and the Oneida Golf and Country Club[44]. By the fall of 2012, they had removed two dams and modified another one in order to improve fish passage for northern pike and other fish[44]. • A group of high school students and teachers have conducted water quality monitoring (e.g., stream flow, pH, dissolved oxygen) for many years upstream in Duck Creek for the Lower Fox River Watershed Monitoring Program[45].

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[38] Bosley 1978: Loss of wetlands on the west shore of Green Bay

[39] Brown County Port and Resource Recovery Cat Island document: https://static1.squarespace.com/static/56ec0372859fd0e272858772/t/574db48fab48de7bc23597a0/1464710289702/2014+Cat+Island+Abstract+Spring.pdf

[40] Frieswyk and Zedler 2007: "Identifying and characterizing dominant plants as an indicator of community condition"

[41] Brown County Port and Resource Recovery Cat Island document: https://static1.squarespace.com/static/56ec0372859fd0e272858772/t/574db48fab48de7bc23597a0/1464710289702/2014+Cat+Island+Abstract+Spring.pdf

[42] Green Bay Fish Working Group Annual Meetings on 4 January 2017

[43] WDNR Phragmites treatment shapefile: "Aerial.shp"

[44] Dam removal project led by the Oneida Tribe: https://greatlakesinform.org/projects-and-progress/498

[45] Lower Fox River Watershed Monitoring Program: https://www.uwgb.edu/watershed/monitoring/overview.asp

	• Over the past several years, UW-Green Bay's Dr. Patrick Robinson, Dr. Christopher Houghton, and others have been leading a project attempting to restore aquatic submergent vegetation on the Duck Creek Delta behind the Cat Island Wave Barrier. They have conducted extensive plant surveys and measured water depth for multiple years. In 2016, they also seeded wild rice along the southeastern edge of this priority area as well as on the south side of the mouth of Duck Creek[46]. • In 2012 and 2017, UW-Green Bay field crews conducted surveys on anurans and birds for the Great Lakes Coastal Wetland Monitoring Program under the leadership of Dr. Robert Howe and Erin Giese[47]. • In 2016-2017, under the guidance of Dr. Howe, Dr. Amy Wolf, and Erin Giese, Tom Prestby surveyed migratory waterfowl within the LGB&FR AOC, including a sampling location on the Cat Island Wave Barrier where he could see the mouth of Duck Creek[48]. • In 2016-2017, the WDNR constructed artificial nesting platforms near this priority area for Forster's Terns, who have successfully nested there both years[8,49]. • In the fall of 2017, UW-Green Bay's Dr. Wolf, Dr. James Horn, and Dr. Howe mapped submerged aquatic vegetation beds throughout the LGB&FR AOC, including this priority area[50]. • UW-Green Bay's Dr. Amy Carrozzino-Lyon, Dr. Patrick Robinson, and Dr. Mathew Dornbush and Duck's Unlimited Brian Glenzinski are trying to re-establish wild rice in the bay of Green Bay (2017-2018), including seeding near the mouth of Duck Creek[51].

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[46] Green Bay Fish Working Group Annual Meeting on 4 January 2017.

[47] Great Lakes Coastal Wetland Monitoring Program: http://www.greatlakeswetlands.org/Home.vbhtml, per Erin Giese

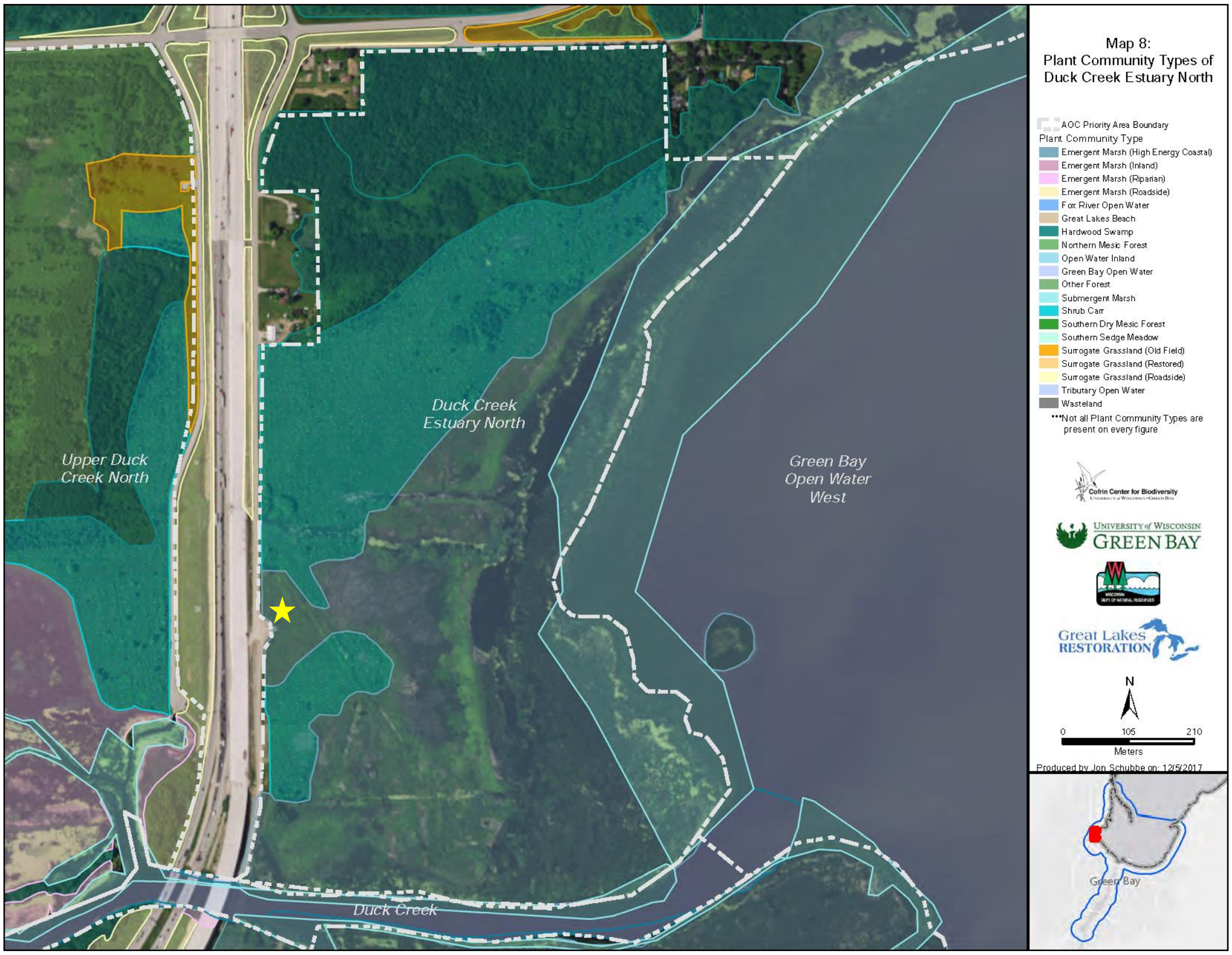
[48] LGB&FR AOC Migratory Waterfowl Surveys 2016-2017 – led by Dr. Amy Wolf, Dr. Bob Howe, Tom Prestby, and Erin Giese

[49] Personal communication with WDNR's Joshua Martinez.

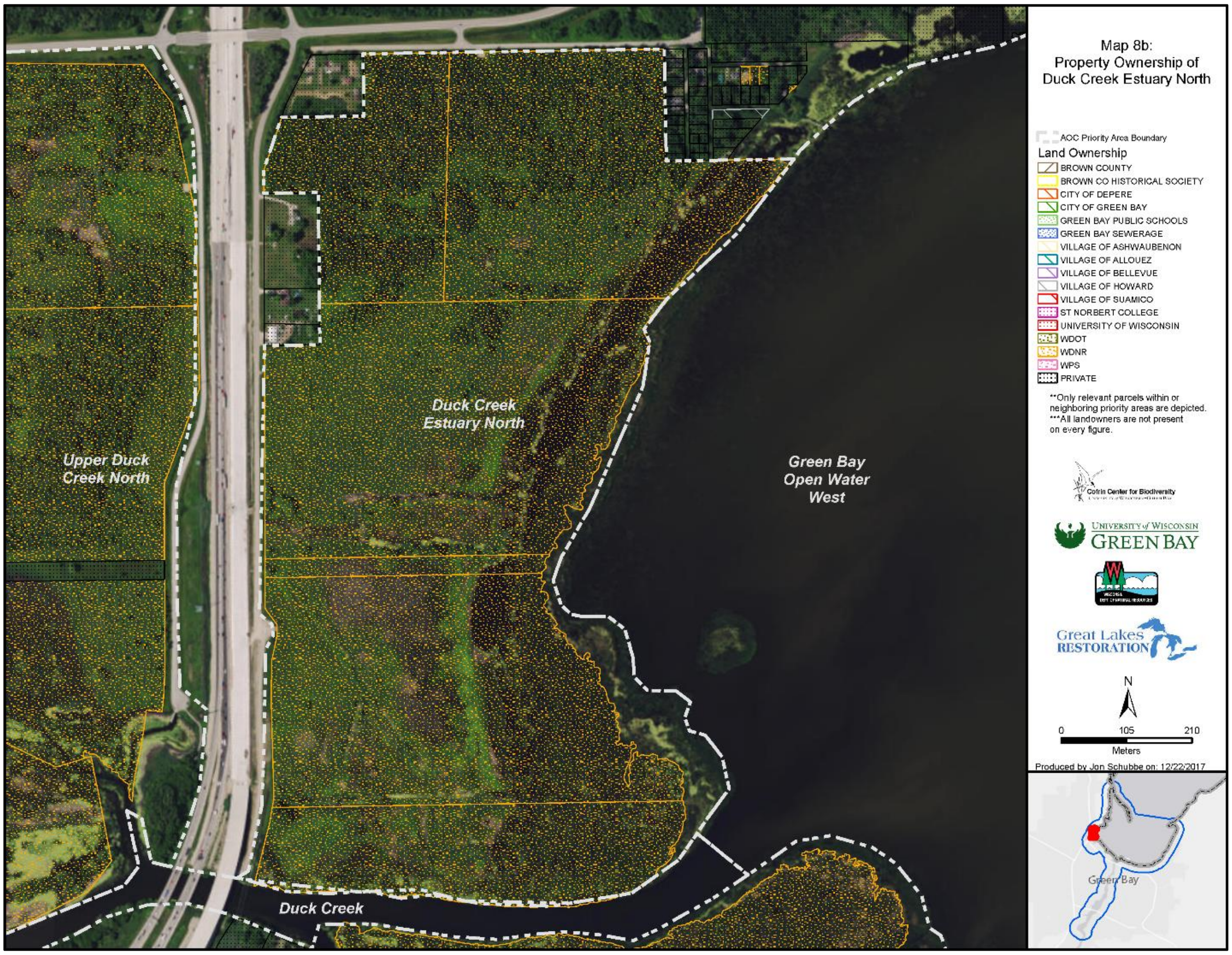
[50] LGB&FR AOC Submerged Aquatic Vegetation Surveys 2017 – led by Dr. Amy Wolf and Dr. James Horn

[51] Wild rice seeding in the lower bay of Green Bay, led by Dr. Amy Carrozzino-Lyon: http://www.ducks.org/conservation/glar/wisconsin/green-bay-partnership-to-improve-wildlife-habit-water-quality

Map of Duck Creek Estuary North’s 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. A small patch of southern sedge meadow was found by Dr. James Horn during the LGB&FR AOC 2016 plant biodiversity hotspot mapping and its general location is indicated by the yellow star below.



Land ownership boundaries at Point Sable. Map made by UW-Green Bay's Jon Schubbe.



Photograph of Duck Creek Estuary North facing northwest. Photograph taken by Erin Giese on 2 December 2016.

Appendix 10.8: Longtail Point

Written by Erin Giese and James Horn

<table>
<tr><td>Location (centroid)</td><td>Lat. 44.608582°, Lon. -87.997278°[1] (NAD 1983, UTM Zone 16N)</td></tr>
<tr><td>Total Area (ha)</td><td>130.17 ha</td></tr>
<tr><td>Area Public Land (ha)</td><td>126.46 ha</td></tr>
<tr><td>Area of Habitat Types Present (ha) and Percent of Each Habitat Type</td><td>
<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&FR AOC)[5]. Habitat types within Longtail Point 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 121.86 ha of natural habitat within Longtail Point.</p>
<table>
<tr><th>Habitat Type</th><th>Area (ha)</th><th>Percent</th></tr>
<tr><td>Emergent Marsh (High Energy Coastal)</td><td>61.38</td><td>50.37</td></tr>
<tr><td>Great Lakes Beach</td><td>1.36</td><td>1.12</td></tr>
<tr><td>Green Bay Open Water</td><td>0.24</td><td>0.20</td></tr>
<tr><td>Hardwood Swamp</td><td>7.46</td><td>6.12</td></tr>
<tr><td>Other Forest</td><td>2.62</td><td>2.15</td></tr>
<tr><td>Submergent Marsh</td><td>48.80</td><td>40.05</td></tr>
</table>
<p><i>Disclaimer! 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.</i></p>
</td></tr>
<tr><td>General Description</td><td>Longtail Point is a peninsula that extends 5 km into lower Green Bay along the west shore in the Village of Suamico. It constitutes the LGB&FR AOC's northwestern-most border, and to the southwest of it in its wave shadow is Dead Horse Bay. Longtail Point largely consists of coastal emergent marsh, though there are thin slivers of hardwood swamp and Great Lakes beach along the northern edge[2,5]. The entire peninsula is subject to the highly dynamic Great Lakes coastal system since it is mostly marsh and can largely be underwater during high Great Lake water levels or dry and sandy during low water years. Like most of the Bay's west shore, it primarily consists of Roscommon muck soils and otherwise standing water[3]. Suamico River empties directly to the peninsula's north side. Despite the fact that Longtail Point is invaded by <i>Phragmites australis</i> (common reed; hereafter referred to as "<i>Phragmites</i>") and the hybrid cattail (<i>Typha</i> × <i>glauca</i>), it is still an important migratory waterfowl stopover site, nursery habitat for many fish species, and breeding habitat for marsh birds. Although Longtail Point is publicly owned, it is not extremely well studied[38], perhaps because it is difficult</td></tr>
</table>

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[1] File "AOC_PriorityAreas.v09_20171212.shp"

[2] LGB&FR AOC comprehensive biota database: file "AOCBiota_DB_ShareableVersion_20171210.accdb"

[3] Soil Survey Geographic (SSURGO) by the United States Department of Agriculture's Natural Resources Conservation Service. Published Dec 2010. Available: http://uwgb.maps.arcgis.com/home/item.html?id=204d94c9b1374de9a21574c9efa31164; accessed 17 Oct 2016.

	to access and is best visited by boat. Because it is publicly owned, the quality and integrity of Longtail Point may be threatened by heavy recreational use (e.g., boating)[7]. However, there is great potential for this site to be enhanced in terms of the quality of its emergent marsh and other habitats. Within the past five years, the Wisconsin Department of Natural Resources has been proactive in terms of tackling the widespread issue of *Phragmites* in the Bay of Green Bay[4]. In 2011, 2012, and 2015, they conducted large-scale aerial and ground sprayings of *Phragmites* along the west shore and other areas, including Longtail Point[4].
Special Features	• Contains one of the largest undeveloped emergent marshes in the entire LGB&FR AOC and at least 4 km of undeveloped Great Lakes beach, a rare LGB&FR AOC and statewide habitat[5]. • Provides critical breeding habitat for marsh bird species, such as Forster's Tern (*Sterna forsteri*), a state endangered species and Wisconsin Wildlife Action Plan Species of Greatest Concern, and American Coot (*Fulica americana*), a state special concern species[2]. • Provides spawning habitat and a nursery for yellow perch (*Perca flavescens*); nursery for walleye (*Sander vitreus*)[6]. • Important migratory bird stopover site, particularly for waterfowl and waterbirds[7]. • Large peninsula that extends outward into lower Green Bay. • Great Egret (*Ardea alba*) and Great Blue Heron (*Ardea herodias*) nesting rookery in trees near the tip of Longtail Point[8]. • Nesting location for Bald Eagle (*Haliaeetus leucocephalus*)[8].
Natural Habitat Communities and Significant Plants (ordered in terms of ecological importance and size/amount)	The vast majority of Longtail Point consists of **emergent high energy marsh**, which is largely dominated by *Phragmites* and hybrid cattail though there are a few native species[5]: • River bulrush (*Bolboschoenus fluviatilis*), locally common[5] • Joint rush (*Juncus nodosus*), moderately common[9] • Giant bur-reed (*Sparganium eurycarpum*), rare[9] • Monkey-flower (*Mimulus ringens*), rare[9] • Ditch stonecrop (*Penthorum sedoides*), rare[9] • Marsh bluegrass (*Poa palustris*), rare[9] • Bebb's sedge (*Carex bebbii*), rare[9] • Soft-stem bulrush (*Schoenoplectus tabernaemontani*), rare[9] A continuous band of **submergent marsh** in Dead Horse Bay flanks the western shore of the peninsula. Native submergent macrophyte species that are dominants are common bladderwort (*Utricularia vulgaris*), coontail (*Ceratophyllum demersum*), and sago pondweed (*Stuckenia pectinata*). Dense mats of forked duckweed (*Lemna trisulca*), floating just beneath the water surface, are moderately common in some areas. So too are beds of the rhizomatous perennial, water celery (*Vallisneria americana*). It is in this area of Dead Horse Bay that small beds of water celery are most common in the LGB&FR AOC. The invasive Eurasian water-milfoil (*Myriophyllum spicatum*) has a discontinuous distribution along the shore, and is moderately common in some areas. Submergent marsh also occurs within the central northern part of the peninsula in a small, relatively high quality area that contains many native emergent plants. Other native aquatic macrophytes include[9]: • Small pondweed (*Potamogeton berchtoldii*), very locally moderately common[9] • Turion duckweed (*Lemna turionifera*), rare throughout[2,9]

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[4] Wisconsin Department of Natural Resources *Phragmites* management: "Aerial_2011_12.shp" and "GLFWRA_Phrag2015_16_aoc.shp"

[5] LGB&FR AOC 2015 habitat field mapping effort: http://uwgb.maps.arcgis.com/home/item.html?id=fdf942b9dd224094b0841a08437f95f0

[6] Wisconsin Department of Natural Resources Fish Trawling Survey Data 1980-2015; sampling points located offshore to south of the Point.

[7] Epstein et al. 2002

[8] AOC Stakeholder's Meeting on 23 June 2015; notes from John Huff and Josh Martinez.

	• Great duckweed (*Spirodela polyrrhiza*), rare throughout • Nodding water-nymph (*Najas flexilis*), rare, mostly throughout[9] • Leafy pondweed (*Potamogeton foliosus*), rare throughout • Common water-milfoil (*Myriophyllum sibiricum*), rare and somewhat local • Common waterweed (*Elodea canadensis*), rare, mostly throughout • Arum-leaved arrowhead (*Sagittaria cuneata*, submergent form), rare and local The third most common habitat at Longtail Point is **hardwood swamp**[5,9], which contains both native and invasive plant species. It is primarily dominated by cottonwood (*Populus deltoides*) and box elder (*Acer negundo*), though it also has green ash (*Fraxinus pennsylvanica*), sandbar willow (*Salix interior*), and river bank grape (*Vitis riparia*)[9]. **Great Lakes beach** habitat extends along nearly the entire northern shoreline of the peninsula and primarily consists of sand and zebra/quagga mussels (*Dreissena* spp.), though they are also lined with some *Phragmites*[5]. Native plants that that inhabit these shorelines include beach rocket (*Cakile edentula* ssp. *edentula* var. *lacustris*), a state special concern species, beach pea (*Lathyrus japonicus* var. *maritimus*), wild four o'clock (*Mirabilis nyctaginea*), and cottonwood[9].
Significant Animals	**Birds**: • Although there are 150-250 possible species, at least 50 bird species have been officially recorded across all seasons, including[2]: o One federal species of concern (Black Tern [*Chlidonias niger*])[2] o Four state endangered species (Caspian Tern [*Hydroprogne caspia*], Forster's Tern [*Sterna forsteri*], Common Tern [*Sterna hirundo*], and Black Tern)[2] ▪ Forster's Tern is listed as an "S1" state rank (critically imperiled) o One state threatened species (Great Egret)[2] ▪ Black Tern and Great Egret are state listed as imperiled o Seven Wisconsin Wildlife Action Plan Species of Greatest Concern (e.g., Caspian, Forster's, and Black Terns, Bald Eagle [*Haliaeetus leucocephalus*], Veery [*Catharus fuscescens*])[2] o Eleven state special concern species (e.g., Common Gallinule [*Gallinula galeata*], Yellow-headed Blackbird [*Xanthocephalus xanthocephalus*], Black-crowned Night-Heron [*Nycticorax nycticorax*], American White Pelican [*Pelecanus erythrorhynchos*], Bald Eagle)[2] ▪ Black-crowned Night-Heron also state listed as imperiled ▪ `Common Gallinule, Yellow-headed Blackbird, and American White Pelican are listed as "S3" state rank (rare or uncommon) o Migratory gulls (e.g., Bonaparte's Gull [*Chroicocephalus philadelphia*]), diving ducks, dabbling ducks, and other waterbirds (e.g., American Coot) use the offshore waters of Longtail Point[10] while raptors and landbirds use the forest and marsh habitats[21] o Although not well documented, many species are known to breed at Longtail Point, especially marsh-nesting species[2,11]: ▪ Forster's Tern, Bald Eagle[8], American Coot, Common Gallinule, Wood Duck (*Aix sponsa*), Mallard (*Anas platyrhynchos*), Yellow-headed Blackbird, Red-winged Blackbird (*Agelaius phoeniceus*), Great Egret[8], and Great Blue Heron[8]

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[9] LGB&FR AOC 2016 botanical surveys

[10] LGB&FR AOC 2016 migratory waterfowl surveys

[11] Wisconsin Breeding Bird Atlas II Project (2015-2019): http://ebird.org/ebird/atlaswi/block/4408758NW?atlasPeriod=EBIRD_ATL_WI_2015& rank=mrec&hs_sortBy=category&hs_o=desc (as of 19 Oct 2016) and http://ebird.org/ebird/atlaswi/block/4408851NE?atlasPeriod=EBIRD_ATL_WI_2015&rank=mrec&hs_sortBy=category&hs_o=desc (as of 19 Oct 2016)

- Longtail Point is officially a “Migratory Bird Concentration Site” according to the Wisconsin Department of Natural Resources[12]

Fish:

- >20 fish species have been recorded offshore near Longtail Point[2,6]:
    - Gizzard shad (*Dorosoma cepedianum*)[6]
    - Trout perch (*Percopsis omiscomaycus*)[6]
    - White bass (*Morone chrysops*)[6]
    - Yellow perch (*Perca flavescens*)[6]
    - Sheepshead (*Aplodinotus grunniens*; aka freshwater drum)[6]
    - Walleye (*Sander vitreus*)[6]
    - Spottail shiner (*Notropis hudsonius*)[6]
    - Northern pike (*Esox lucius*)[6]
    - Spotted musky (*Esox masquinongy*; aka muskellunge)[6]
    - Banded killifish (*Fundulus diaphanous*), a state special concern species and Wisconsin Wildlife Action Plan Species of Greatest Concern[2]

Mammals:

- Although ~50 mammal species are known or are expected to occur along the west shore (as noted in Roznik 1979)[13], four mammal species have been officially recorded in recent years: American mink (*Neovison vison*), muskrat (*Ondatra zibethicus*), North American river otter (*Lontra canadensis*), coyote (*Canis latrans*)[14,15].

Anurans:

- Six anuran (frog/toad) species[2], many of whom likely breed at Longtail:
    - American bullfrog (*Lithobates catesbeianus*), American toad (*Bufo americanus*), eastern gray treefrog (*Hyla versicolor*), green frog (*Lithobates clamitans*), northern leopard frog (*Lithobates pipiens*), and spring peeper (*Pseudacris crucifer*)
        - Northern leopard frog is both a federal and state species of special concern. American bullfrog is a state species of special concern.
- Eastern tiger (*Ambystoma tigrinum*) and blue-spotted salamanders (*Ambystoma laterale*) are expected to occur along the west shore of Green Bay (as noted in Roznik 1979)[13], though neither has been officially reported at Longtail Point.

Arthropods:

- Over 40 species of arthropods have been recorded at Longtail Point, including many important aquatic species, such as[2]:
    - Predaceous diving beetles (*Hydrovatus* sp., *Hygrotus* sp.)
    - Long-horn caddisfly (*Oecetis* sp.)
    - Microcaddisfly (*Oxyethira* sp., *Agraylea* sp.)
    - Small squaregilled mayfly (*Caenis* sp.)
    - Water boatmen (*Trichocorixa* sp.)
    - Pygmy backswimmer (*Neoplea* sp.)
    - Water beetle (*Laccophilus* sp.)
    - Amphipod (*Gammarus* sp.)
    - Whirligig beetle (*Dineutus* sp.)

Mollusks:

- Pea clams (Pisidiidae [family]) and a few groups of snails[2]:
    - Bladder snail (Physidae [family])

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[12] Wisconsin Department of Natural Resources. 2009. Wisconsin Natural Heritage Working List. http://dnr.wi.gov/topic/NHI/WList.html. (Accessed: 1 Nov 2014).

[13] Green Bay West Shores Master Plan Concept Element 1979 by Roznik et al.

[14] Wisconsin Department of Natural Resources Technical Report PUB-LF-073.

[15] Wisconsin Department of Natural Resources 2015 muskrat house survey

	o Ramshorn snail (Planorbidae [family]) o Pond snails (*Pseudosuccinea* sp., *Stagnicola* sp.) **Reptiles**: • Although not well studied, several reptiles are expected to occur along the west shore of Green Bay (as noted in Roznik 1979), including common garter snake (*Thamnophis sirtalis*) and eastern snapping turtle (*Chelydra serpentina*)[13]. Painted turtle (*Chrysemys picta*) has been officially recorded at Longtail Point[2].
Habitat Quality	Overall, the ecological quality of Longtail Point is relatively low though there are pockets of higher quality areas depending on the habitat type. 1. Emergent Marsh[9] o Primarily invaded by *Phragmites*, with hybrid cattail and purple loosestrife also present in many areas, making the marsh habitat relatively low in ecological quality. Even so, there are still many smaller areas with native plants, such as joint rush and blue-joint grass, and pockets of submergent vegetation that includes many natives. 2. Submergent Marsh[9] o Overall, in moderate to increasingly good quality northward toward the apex of Dead Horse Bay. The encroachment of Eurasian water-milfoil (*Myriophyllum spicatum*), the only invasive species present here, is locally moderately common. Includes the largest concentration of water celery (*Vallisneria americana*) beds in the LGB&FR AOC. Some areas (particularly southward) have vegetation heavily covered with a brown periphyton. 3. Hardwood Swamp[9] o Dominated by cottonwood and box elder (*Acer negundo*), although invaded by *Phragmites*. 4. Great Lakes Beach[9] o Overall, much of the beach habitat is low in quality because of encroachment by *Phragmites*. However, there is a narrow stretch of beach on the eastern-most third of the peninsula that, although largely barren of vegetation, has a few individuals of beach rocket. Beach habitat at the southeastern tip of the peninsula also has characteristic species. Such areas therefore partially resembles historical Great Lakes beach habitat.
Significant Invasive Species Issues	**Invasive Plant Species**: Each of these species outcompetes and crowds out native plants: • Common reed (*Phragmites australis*)[2,5,9] o Common and continuing problem; occurs along shoreline in Great Lakes beach, emergent marsh, and hardwood swamp; some management has occurred in recent years in open areas (2011-12, 2015-16) • Hybrid cattail (*Typha* × *glauca*)[2,5,9] o Somewhat common and continuing problem; occurs in emergent marsh; management unknown • Eurasian water-milfoil (*Myriophyllum spicatum*)[9] o Some occurs in submergent marsh; management unknown • Purple loosestrife (*Lythrum salicaria*)[9] o Some occurs in emergent marsh; management unknown • Canada thistle (*Cirsium arvense*)[2,9] o Very little occurs in emergent marsh; management unknown • Common hemp-nettle (*Galeopsis tetrahit*)[2,9] o Very little occurs in emergent marsh; management unknown • Others have been reported at Longtail Point[2]: o Field bindweed (*Convolvulus arvensis*)

  - Lesser burrdock (*Arctium minus*)
  - Orange hawkweed (*Hieracium aurantiacum*)

Exotic Plant Species[2]: Their presence has been documented though the extent to which they occur at Longtail Point is unknown.

  - Bittersweet nightshade (*Solanum dulcamara*)
  - Butter-and-eggs (*Linaria vulgaris*)
  - Common dandelion (*Taraxacum officinale*)
  - Common dogmustard (*Erucastrum gallicum*)
  - Common mullein (*Verbascum thapsus*)

Invasive Animal Species:

- *Birds*
  - European Starling (*Sturnus vulgaris*)[2]
    - Poses some threat to native species, particularly cavity nesters (e.g., Tree Swallow), by outcompeting them and occupying potential nest sites; not currently being managed.
  - Other exotic or invasive bird species occur at Longtail Point[2,11], notably Brown-headed Cowbird (*Molothrus ater*), House Sparrow (*Passer domesticus*), and Rock Pigeon (*Columba livia*); however, these species generally do not significantly affect native birds at Longtail because they typically inhabit human-inhabited areas (e.g., developed or agricultural areas).

- *Fish*[6]
  - Alewife (*Alosa pseudoharengus*)[16]
    - Poses a threat to native fish species by consuming zooplankton and disturbing the natural food web; not currently being managed
  - Common carp (*Cyprinus carpio*)[17]
    - Destroy vegetation by uprooting plants and increasing cloudiness of water; not currently being managed
  - Rainbow smelt (*Osmerus mordax*)[18]
    - Negatively affect uncommon to rare native fish species; not currently being managed
  - Round goby (*Neogobius melanostomus*)[19]
    - Prey on small native fish and eggs (e.g., darters) and outcompete similarly sized native fish; not currently being managed
  - White perch (*Morone americana*)[20]
    - Prey on native fish eggs, such as walleye; not currently being managed

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[16] 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.

[17] 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.

[18] 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.

[19] 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.

[20] 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.

	• *Freshwater mussels*
	  o Zebra mussel (*Dreissena polymorpha*)[21]
	    ▪ Poses threat to native freshwater mussels; not currently being managed

Management and Restoration Recommendations	• Continue current invasive plant species management efforts to control invasives noted above (e.g., *Phragmites*, hybrid cattail, purple loosestrife)[14]. • Ensure that native emergent (e.g., soft-stem bulrush [*Schoenoplectus tabernaemontani*]) and submergent plants replace their invasive counterparts to provide high quality fish and wildlife habitat. • Restore Great Lakes beach habitat by removing invasive plant species, which will improve shorebird habitat. o Recreate potential breeding habitat for the federally endangered Piping Plover (*Charadrius melodus*) by providing a few long stretches of Great Lakes beach with sand, cobble, or shells with little to no vegetation and preventing human recreation. Historically, Longtail Point was one of the best potential breeding sites for Piping Plovers[22]. • Improve substrate for freshwater mussels and crayfish, which help improve water quality and provide food for migratory waterfowl. • Plant native woody shrubs (e.g., river bank grape vine, raspberry [*Rubus idaeus*]) in the small hardwood swamp to provide food to migratory songbirds. • Continue existing sustainable forestry management practices to maintain a diversity of tree sizes and ages[14]. • Limit recreational use and boating during breeding bird season (May-August). • Conduct biotic inventories along AOC shoreline and if necessary re-establish populations of native turtle species and other beach specialists. • Identify critical buffer habitats and shorelines with potential den sites for mink, otter, and other shoreline wildlife species. • Continue efforts to re-establish nesting colonies of Forster's and Black Terns. • Designate and protect sensitive areas.

Reference Links and Documents	**Links**:
	• Background information on Longtail Point prepared by the Wisconsin Department of Natural Resources: http://dnr.wi.gov/topic/lands/GBWS/longtail.html.
	• History of Longtail Point and its Lighthouses prepared by the Lighthouse Friends Group: http://www.lighthousefriends.com/light.asp?ID=634.
	
	Reference Documents:
	• Disterhaft, K. 2013. Changes in fish assemblages of Lake Michigan's Green Bay following the introduction of Dreissenid mussels and round goby (*Neogobius melanostomus*) during 1980-2010. Master's thesis from the University of Wisconsin-Green Bay.
	• Epstein, E.J., E. Spencer, and D. Feldkirchner. 2002. A data compilation and assessment of coastal wetlands of Wisconsin's Great Lakes, final report. Natural Heritage Program, Bureau of Endangered Resources, Wisconsin Department of Natural Resources, Madison, WI, USA. PUBL ER-803 2002.
	  o Available: http://dnr.wi.gov/files/pdf/pubs/er/er0803.pdf.
	• Frieswyk, C.B., C.A. Johnston, and J.B. Zedler. 2007. Identifying and characterizing dominant plants as an indicator of community condition. Journal of Great Lakes Research. 33(3):125-135.
	  o Available: http://glei.nrri.umn.edu/default/documents/frieswyk_jglr_2007.pdf

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[21] Wisconsin Department of Natural Resources Technical Report PUBL ER-818 2010: file "WDNR2010_RapidEcologicalAssmtForGBWestShores WildlifeArea.pdf"

[22] Personal communication with Thomas Erdman.

	• 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. • Mossman, M.J. 1989. Wisconsin Forster's Tern Recovery Plan. Passenger Pigeon 51(2):171-186. http://images.library.wisc.edu/EcoNatRes/EFacs/PassPigeon/ppv51no02/reference/econatres.pp51n02.mmossman.pdf • Wisconsin Department of Natural Resources. 1979. Green Bay West Shores Master Plan Concept Element. Property Task Force: F. Roznik, J. Raber, D. Olson, L. Lintereur, and L. Kernen. • Wisconsin Department of Natural Resources' Natural Heritage Inventory Program (primary author: Christina Isenring). 2010. Rapid ecological assessment for the Green Bay West Shores State Wildlife Area: a summary of biodiversity values focusing on rare plants, selected rare animals, and high-quality natural communities in preparation for the development of a new property master plan. Technical Report PUBL ER-818 2010. • Wisconsin Department of Natural Resources. 2013. Regional and property analysis: Green Bay Planning Group. Technical Report PUB-LF-073. • Wisconsin Department of Natural Resources. 2014. Green Bay Planning Group Master Plan. Technical Report PUB-LF-075.
Site History (e.g., original vegetation, past conservation projects)	In the early 1630s, Frenchman Jean Nicolet first arrived in lower Green Bay when it was primarily inhabited by Native American tribes[23]. Two Native American camp sites were located on Longtail Point and were likely from the Menominee Tribe though there was a Potawotami village near the mouth of the Big Suamico River on the north side of Longtail Point[24]. Lower Green Bay consisted of large beds of wild rice (*Zizania* sp.) and wild celery (*Vallisneria americana*), extensive emergent marsh (*Schoenoplectus* sp., cattail), sedge meadows (*Calamagrostis canadensis*), shrub carr (e.g., *Cornus* spp., *Salix* spp.), swamps, and wet conifer forest (black spruce [*Picea mariana*], balsam fir [*Abies balsamea*])[25,26,27,28,29]. Between the late 1600s and 1800s, European fur trade, duck hunting, fishing, logging, shipping, and agriculture were important early industries in lower Green Bay[30,31,32]. In the early 1800s, there were a few small settlements and farms of Europeans and Native Americans in the lower bay[31]. In the 1840s, Longtail Point consisted of marsh (called "swamp" in Dorney 1975)[24]. Many visitors to lower Green Bay arrived by ships from Lake Michigan since boats were a fast form of travel at the time. In the early 1800s, the importance of shipping was recognized; therefore, on 3 March 1837, Congress allotted $5,000 for building a lighthouse in lower Green Bay to assist ships with navigation. Although the U.S. Navy

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

[24] The vegetation pattern around Green Bay in the 1840s as related to geology, soils, and land use by Indians with a detailed look at the Townships of Scott, Green Bay, and Suamico by John Dorney, 1975. File "Dorney1975_VegetationPatternGreenBay1840s.pdf".

[25] Arthur C. Neville's Map of Historic Sites on Green Bay, Wisconsin 1669-1689. Available: http://s3.amazonaws.com/labaye/data/Bay%20Settle ment%20Map%20WI%20Historical%20Bulletin%201926.pdf (accessed on 24 Oct 2016).

[26] 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).

[27] 1845 Chart of Green Bay. Available http://s3.amazonaws.com/labaye/data/1845%20Chart%20of%20Green%20Bay.pdf (accessed on 24 Oct 2016).

[28] 1820s Fox River Military Road Map to Ft. Crawford. Available: http://s3.amazonaws.com/labaye/data/1820s%20Fox%20River%20Military%20 Road%20Map%20to%20Ft.%20Crawford.pdf (accessed on 24 Oct 2016).

[29] Personal communication with Thomas Erdman.

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

[31] 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).

[32] 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).

first considered putting a lighthouse on Grassy Island (later determined to be too small and unstable), Naval Lieutenant, James T. Homans, proposed building the lighthouse on Longtail Point. However, Congress did not provide funds until ten years later (c1847) and gave him just $4,000 to build it. A 51.5 ft tall lighthouse made out of limestone was built with a large lantern used for providing ships with light, and a lighthouse keeper's home was also constructed. The Longtail Point lighthouse became active in 1848. A second lighthouse was erected in the late 1850s on higher ground due to high water levels and was more "house-like" in appearance for the lighthouse keeper to live. A third lighthouse was built off the pier near the tip of Longtail Point to be closer to the channel for viewing after a ship sunk in the late 1890s[33].

In 1936, the majority of Longtail Point officially joined the federal National Wildlife Refuge system and became known as the Longtail Point Migratory Waterfowl Refuge[33,34]. In 1961, this refuge was given to the state, at which point it became a part of the Green Bay West Shores State Wildlife Areas, which was established in 1948 (starting with Sensiba through the 1960s and 1970s with other places like Peshtigo Harbor, Oconto Marsh, etc.)[35] The second lighthouse was removed around the time Longtail was a national wildlife refuge, and the third lighthouse was later destroyed by the 9 April 1973 storm[33,22]. During these high water periods of the 1970s, Longtail Point became a series of barrier islands and was disconnected from the mainland[36]. This is no surprise given that Longtail is a part of the highly dynamic Great Lakes coastal system. Interestingly, the first, original lighthouse still stands today[33].

Prior to the arrival of many invasive plants species in the late 1990s, the emergent marsh at Longtail Point consisted of soft-stem bulrush (*Schoenoplectus tabernaemontani*) and three-square bulrush (*Schoenoplectus pungens*). There also used to be a sedge meadow consisting of blue-joint grass (*Calamagrostis canadensis*) and cattails (*Typha* spp.), hardwood swamp, and a small amount of shrub carr[34]. In the 1960s, Little Gulls (*Hydrocoloeus minutus*) and Forster's Terns regularly nested on floating mats of vegetation at Longtail Point[22].

In 1999 and 2002, more land parcels were added to what now makes up Longtail Point State Wildlife Area. In the late 1990s and early 2000s, *Phragmites*, the hybrid cattail, and purple loosestrife arrived in lower Green Bay and invaded much of the area, including other west shore wetlands. Unfortunately, these aggressive species have now outcompeted many of the native plant species and dominate Longtail's emergent marshes[9]. In 2011 and 2012, the Wisconsin Department of Natural Resources (WDNR) acquired Great Lakes Restoration Initiative funding to conduct aerial herbicide spraying to combat the *Phragmites* and lyme grass (*Leymus arenarius*) across all of the Green Bay West Shores State Wildlife Areas, including Longtail Point. Since then, Ducks Unlimited and the WDNR have done follow-up *Phragmites* treatment as needed[34] at multiple sites, which includes a relatively large spraying effort in 2015 and 2016, at which point Longtail was sprayed[4,34,37]. As with most state-owned properties, the WDNR also manages Longtail's forest by harvesting timber[34].

Today, Longtail Point is used heavily for recreational activities, such as hunting, boating, trapping, and fishing. Most hunt for waterfowl and white-tailed deer, trap for otter, mink, etc., and fish for perch and northern pike. During the summer months, many recreational boaters visit the sandy beaches at Longtail Point. Others kayak or canoe offshore. The WDNR maintains two small parking areas, boat launches, and

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[33] Lighthouse Friends Webpage on Longtail Point: http://www.lighthousefriends.com/light.asp?ID=634 (accessed on 20 Oct 2016).

[34] Wisconsin Department of Natural Resources Technical Report Technical Report PUB-LF-075

[35] Wisconsin Department of Natural Resources Technical Report Technical Report PUB-LF-073

[36] Brown County's Online GIS Portal (summer 1978 aerial imagery); http://maps.gis.co.brown.wi.us/geoprime/ (accessed on 20 Oct 2016).

[37] Ducks Unlimited and Wisconsin Department of Natural Resources Phragmites Treatment 2015-16. File "DNR grant project descriptions.docx".

	picnic area to provide recreational users with access to Longtail Point. The Village of Suamico is working with the WDNR to establish the remaining stone lighthouse as an important historical location[34]. In recent years, the WDNR has been conducting long-term monitoring of fish populations offshore Longtail Point since 1980[6] as well as the extent of invasive plant species. There have been a few studies on breeding marsh birds, mammals (e.g., muskrats), fish, plants, and migratory waterfowl from 2011 to 2016 by many groups[9,10,15,38], and the WDNR monitors nesting terns and tracks waterfowl for hunting. For the past two years, the WDNR has constructed and placed artificial nesting platforms in protected emergent marsh at Longtail Point to try and attract Black and Forster's Terns to nest there. While Black Terns have been found in the LGB&FR AOC during the breeding season, they have not used these nesting platforms, and no one has confirmed breeding for this species yet in the lower bay in recent years[39]. Adult and fledgling Forster's Terns, however, have utilized these Black Tern platforms for loafing[39], though Forster's Terns have not used these platforms for nesting either. Since 1986, NEW Water has also been collecting long-term water quality data at two locations offshore Longtail (and other areas in Lower Green Bay), including parameters like dissolved oxygen, water clarity, pH, and conductivity[38]. Dr. Jerry Kaster and Christopher Groff from UW-Milwaukee released 120 million mayfly (*Hexagenia* sp.) eggs into the bay of Green Bay, including at Longtail Point, between 2014 and 2016 in an attempt to reintroduce this important invertebrate back into the Green Bay ecosystem[40]. In 2016, they witnessed the first *Hexagenia* emergence in over 60 years when they found adult exuviae at Longtail Point as well as in Door County and Little Tail Point[40]. The U.S. Fish and Wildlife Service coordinate an early detection and monitoring program of aquatic invasive species in Lake Michigan, and many of their sampling locations are in the LGB&FR AOC, including along the outer edges of Dead Horse Bay by Longtail Point[40]. They survey for ichthyoplankton, carp, macro-invertebrates, and nearshore fishes[40]. Biologists from the Great Lakes Coastal Wetland Monitoring Program have surveyed Longtail Point for birds in 2011 and 2016-2017 and for fish, invertebrates, and vegetation in 2012 and 2017. Still, more research is needed at Longtail Point; however, there is great potential for this site to have additional monitoring efforts and to enhance the quality of its emergent marsh and other habitats.

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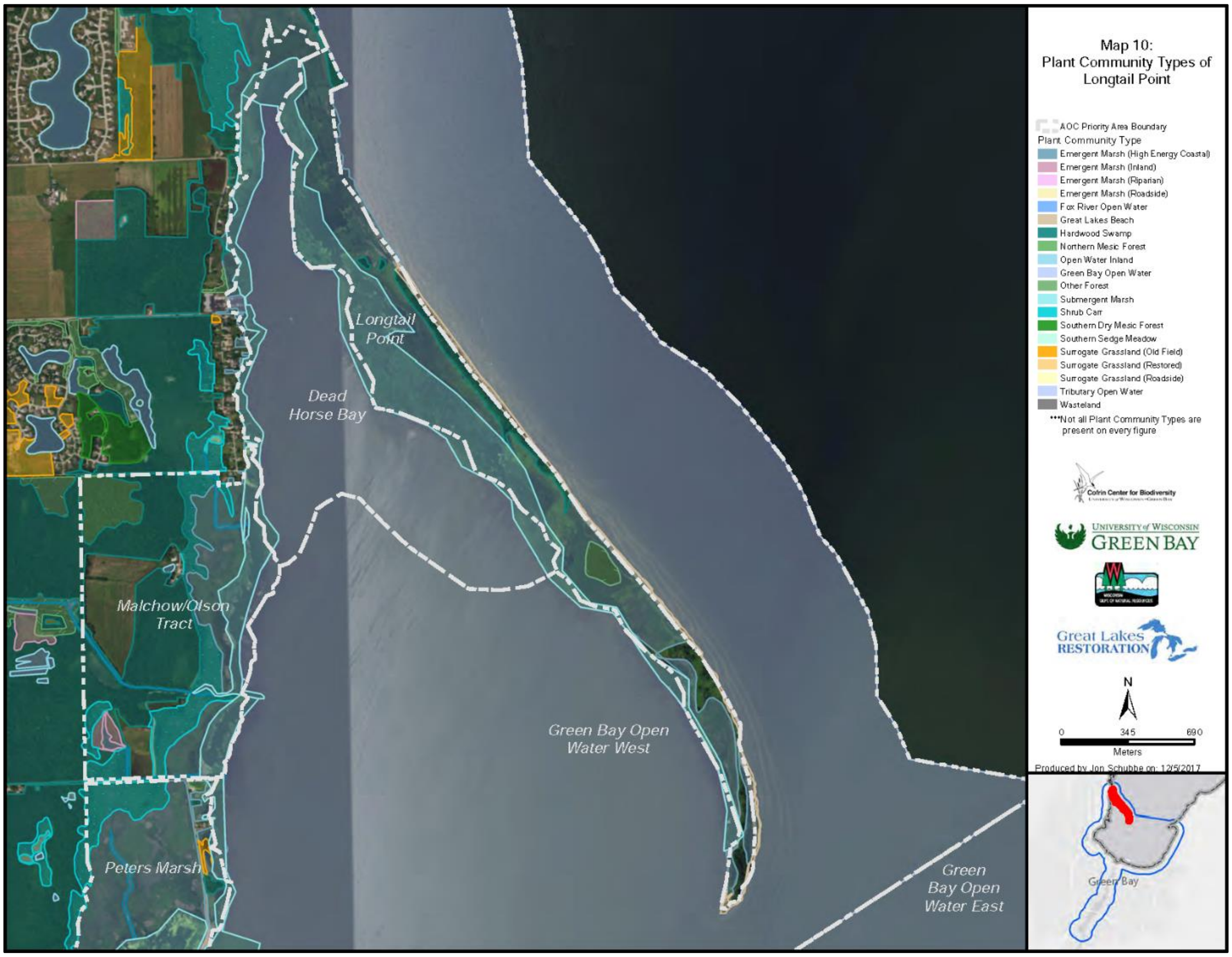
[38] LGB&FR AOC Comprehensive Conservation Project Catalogue

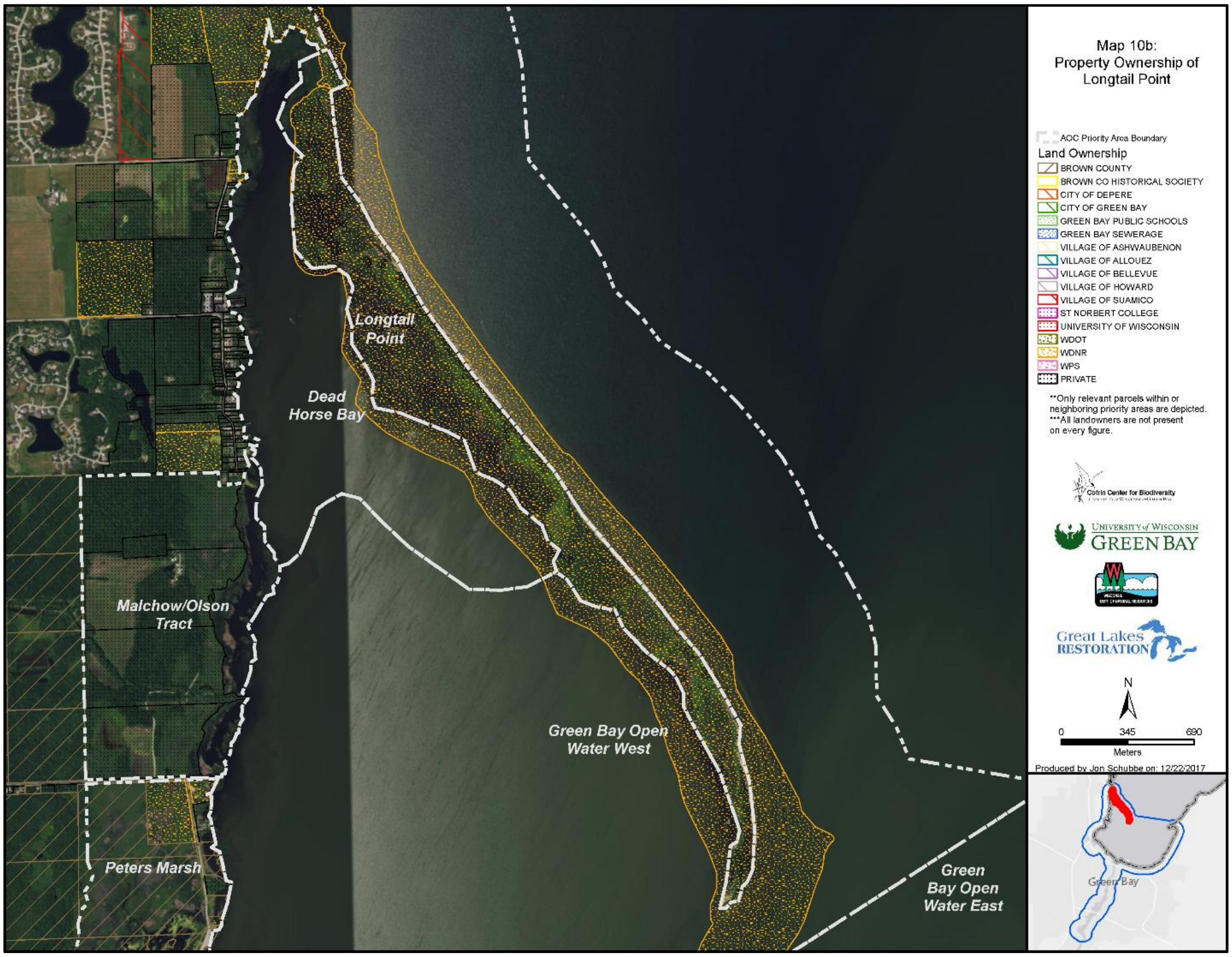
[39] Personal communication with Joshua Martinez

[40] Green Bay Fish Working Group Annual Meetings on 4 January 2017

Map of Longtail Point's 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.



Land ownership boundaries at Longtail Point. Map made by UW-Green Bay's Jon Schubbe.



Photograph of Longtail Point facing northwest. Photograph taken by Erin Giese on 2 December 2016.

Photograph of Longtail Point facing north. Photograph taken by Erin Giese on 2 December 2016.

Photograph of Longtail Point facing west. Photograph taken by Erin Giese on 2 December 2016.

Appendix 10.9: Malchow/Olson Tract

Written by Erin Giese and James Horn

<table>
<tr><td>**Location** (centroid)</td><td>Lat. 44.599540°, Lon. -88.017854°[1] (NAD 1983, UTM Zone 16N)</td></tr>
<tr><td>**Total Area** (ha)</td><td>139.01 ha</td></tr>
<tr><td>**Area Public Land** (ha)</td><td>0 ha - This entire property privately owned, though it is surrounded by publicly-owned land.</td></tr>
<tr><td>**Area of Habitat Types Present (ha) and Percent of Each Habitat Type**</td><td>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&FR AOC)[3]. Habitat types within the Malchow/Olson Tract 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 118.64 ha of natural habitat within Malchow/Olson Tract.
<table>
<tr><th>Habitat Type</th><th>Area (ha)</th><th>Percent</th></tr>
<tr><td>Emergent Marsh (High Energy Coastal)</td><td>21.30</td><td>17.96</td></tr>
<tr><td>Emergent Marsh (Inland)</td><td>1.57</td><td>1.33</td></tr>
<tr><td>Green Bay Open Water</td><td>4.79</td><td>4.04</td></tr>
<tr><td>Hardwood Swamp</td><td>43.92</td><td>37.02</td></tr>
<tr><td>Northern Mesic Forest</td><td>7.94</td><td>6.69</td></tr>
<tr><td>Open Water Inland</td><td>0.88</td><td>0.74</td></tr>
<tr><td>Shrub Carr</td><td>20.18</td><td>17.01</td></tr>
<tr><td>Submergent Marsh</td><td>16.65</td><td>14.04</td></tr>
<tr><td>Tributary Open Water</td><td>1.40</td><td>1.18</td></tr>
</table>
Disclaimer! *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 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, late summer/fall 2016 and 2017. Great Lakes water levels were much higher in 2016 and 2017 than in July 2015.*</td></tr>
<tr><td>**General Description**</td><td>The Malchow/Olson Tract is a relatively large, privately owned priority area located along the west shore of the bay of Green Bay just south of Longtail Point, which constitutes the LGB&FR AOC northwestern-most border. Since the late 1890s (estimated), this land has been owned by the descendants of the now deceased William and Gordon Malchow[32]. Before Gordon and his wife Ethel Malchow died, their one wish was for their children to protect this family property for the purposes of wildlife preservation[32]. Thanks to this family's perseverance, led by Eileen Olson (Gordon and Ethel Malchow's daughter) and her relatives, the Malchow/Olson Tract has largely been untouched and undisturbed over the past 100+ years with the exception of the family's farmland and houses. Like much of the west shore, it primarily consists of Tedrow loamy fine sand and Roscommon muck soils[2]. Within the entire LGB&FR AOC, parts of this property's emergent marsh and nearly all of its hardwood swamp have the</td></tr>
</table>

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[1] File "AOC_PriorityAreas.v09_20171212.shp"

[2] Soil Survey Geographic (SSURGO) by the United States Department of Agriculture's Natural Resources Conservation Service. Published Dec 2010. Available: http://uwgb.maps.arcgis.com/home/item.html?id=204d94c9b1374de9a21574c9efa31164; accessed 1 Nov 2016.

	highest ecological quality for these habitat types because they have high native plant diversity and little to no invasives[4]. It is one of the few places in the LGB&FR AOC that still contains the historical mosaic of submergent and emergent marsh that naturally grades into southern sedge meadow, shrub carr, and hardwood swamp[3,4,5]. It provides critical habitat for northern pike (*Esox lucius*), muskrats, breeding and migratory birds, and migratory waterfowl offshore and is a refuge for many native plants that are locally uncommon to the LGB&FR AOC[3,4,7,8,9,40]. A few invasive plants have been found here in recent years, including *Phragmites australis* (common reed; hereafter referred to as "*Phragmites*") and reed canary grass (*Phalaris arundinacea*)[3,4], however, the Wisconsin Department of Natural Resources (WDNR) has treated *Phragmites* in 2011-2012 with aerial spraying and on the ground treatment in 2015-2016[43]. Because of these efforts, the amount of *Phragmites* present today is very minimal[4]. Fish, plants, birds, and anurans (frogs + toads) have been sampled at this site in the past several years, though additional research and monitoring are still needed[40]. Based on what is currently known, every effort should be made to protect this property because it provides essential fish and wildlife habitat, which helps support sustainable health fish and wildlife populations within the LGB&FR AOC.
Special Features	• Comprises a natural, relatively undisturbed landscape of emergent marsh that grades into southern sedge meadow, shrub carr, and hardwood swamp; this landscape describes the historical mosaic originally found in lower Green Bay[3,4,5]. • Contains the best coastal emergent marsh in terms of ecological quality in the entire LGB&FR AOC because of its high native plant diversity. This marsh is largely dominated by soft-stem bulrush (*Schoenoplectus tabernaemontani*) and blue-joint grass (*Calamagrostis canadensis*)[4]. • Contains a high quality swamp white oak (*Quercus bicolor*) hardwood swamp with a dense understory of the native shrub, common winterberry (*Ilex verticillata*)[4]. • Contains one of the largest stretches of shrub carr in the LGB&FR AOC that is dominated by speckled alder (*Alnus incana*) and an appreciable patch of southern sedge meadow (perhaps best considered a 'tussock meadow,' as it is c. 85% dominated by the tussock-forming blue-joint grass, a rare habitat in the LGB&FR AOC and across the state[4]. • Provides important spawning habitat and migration corridors for northern pike (*Esox lucius*)[40,42]. • Important habitat for muskrats in the emergent marsh[6]. • Significant breeding habitat for many forest and marsh-nesting bird species[7] and migratory habitat for waterfowl and songbirds[7,8].
Natural Habitat Communities and Significant Plants (ordered in terms of ecological importance and size/amount)	Approximately half of the Malchow/Olson Tract consists of **emergent high energy marsh**, which is found across the eastern edge of this priority area's boundary[4]. Although some invasive plants have been here for a few years (e.g., *Phragmites*, hybrid cattail [*Typha × glauca*]), *Phragmites* has recently been treated by the WDNR in 2011-2012 and 2015-2016[43]. Because of these herbicide treatments, an extremely high diversity of native forbs and graminoids can be found in place of the *Phragmites*, especially in the highest quality portion of the marsh (located in the central portion of this priority area)[4]. This section of the marsh is by far the best emergent marsh in the entire LGB&FR AOC in terms of plant diversity[4]. Natives include[4]: • Soft-stem bulrush (*Schoenoplectus tabernaemontani*), moderately common • Blue-joint grass (*Calamagrostis canadensis*), moderately common • Canadian rush (*Juncus canadensis*), rare • Marsh bellflower (*Campanula aparinoides*), rare • Swamp loosestrife (*Decodon verticillatus*), rare

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[3] LGB&FR AOC 2015 habitat field mapping effort
[4] LGB&FR AOC 2016 botanical surveys
[5] Bertrand et al. 1976: The Green Bay Watershed Past/Present/Future.
[6] Wisconsin Department of Natural Resources 2015 muskrat house survey
[7] LGB&FR AOC comprehensive biota database: file "AOCBiota_DB_ShareableVersion_20161006.accdb"
[8] LGB&FR AOC 2016 migratory waterfowl surveys

- Bulblet water-hemlock (*Cicuta bulbifera*), rare
- Bristly sedge (*Carex comosa*), rare
- False dragonhead (*Physostegia virginiana*), rare
- Hemlock water-parsnip (*Sium suave*), rare

The second largest habitat type is **hardwood swamp**, which is located along the western edge of the Malchow/Olson Tract from Oak Ridge Lane to the north and Lineville Road to the south[4].

- Along the northcentral and northwestern edges of this priority area is a hardwood swamp largely dominated by red maple (*Acer rubrum*) in the canopy and with a moderate subcanopy of common serviceberry (*Amelanchier arborea*). Shrubs are largely absent here, but the herbaceous understory is exceptionally well developed and unusual in being dominated by a diversity of fern species, including sensitive fern (*Onoclea sensibilis*), royal fern (*Osmunda regalis*), interrupted fern (*Osmunda claytoniana*), and marsh fern (*Thelypteris palustris*). This hardwood swamp is one of the best in the entire LGB&FR AOC and contains an impressive diversity of other herbaceous natives, including interior sedge (*Carex interior*), weak sedge (*Carex debilis*), big white trillium (*Trillium grandiflorum*), and the uncommon, WI special concern species, marsh bedstraw (*Galium palustre*). Significantly, invasive plant species are almost absent here.
- In the center of the property to the west of Dirt Road is a green ash-dominated hardwood swamp with a relatively thick understory of common winterberry and other natives:
  - Fowl manna grass (*Glyceria striata*), moderately common
  - Small-spike false nettle (*Boehmeria cylindrica*), moderately common
  - Sensitive fern (*Onoclea sensibilis*), moderately common
  - Common hop sedge (*Carex lupulina*), rare
  - Greater bladder sedge (*Carex intumescens*), rare
  - Needle spike-rush (*Eleocharis acicularis*), rare
- In the southcentral third of the property, there a swamp white oak hardwood swamp with some green ash and white birch, though a relatively dense understory of the invasive shrub, glossy buckthorn (*Frangula alnus*).

The Malchow/Olson Tract also contains one of the largest, continuous stretches of **shrub carr** in the LGB&FR AOC[3]. Unlike much shrub carr vegetation in this region today, the shrub carr here is largely dominated by speckled alder (*Alnus incana*)[4]. Most of it is adjacent to the high energy emergent marsh, though some surrounds a small pond in the southwestern corner. Although some reed canary grass and other invasives can be found here, many natives are present[4]:

- Blue-joint grass (*Calamagrostis canadensis*), moderately common
- Lake sedge (*Carex lacustris*), moderately common
- Small-spike false nettle (*Boehmeria cylindrica*), moderately common
- Marsh pea (*Lathyrus palustris*), rare
- Meadow willow (*Salix petiolaris*), rare
- Red-osier dogwood (*Cornus sericea*), rare
- Peach-leaved willow (*Salix amygdaloides*), rare
- Common three-square bulrush (*Schoenoplectus pungens*), rare

Off the shore of the Malchow/Olson Tract, at the eastern periphery of this priority area, is a continuous band of **submergent marsh**. Submergent marsh also extends up an unnamed creek that flows through the property into the bay of Green Bay. Two invasive submergent macrophytes occur in this priority area. Eurasian water-milfoil (*Myriophyllum spicatum*) is present throughout, and may be locally common. Curly-leaf pondweed (*Potamogeton crispus*) is also present here (and rare) but only in the creek. Native submergent macrophyte dominants of these marshes are coontail (*Ceratophyllum demersum*), common bladderwort (*Utricularia vulgaris*), and sago pondweed (*Stuckenia pectinata*). Turion duckweed (*Lemna turionifera*) is the most

	common duckweed species. Noteworthy rare species include water star-grass (*Heteranthera dubia*), which reaches the northern limit of its distribution along the west shore near the northern boundary of this priority area, and water celery (*Vallisneria americana*). Overall, the submergent marshes of the Malchow/Olson Tract are of moderate quality relative to those of other priority areas in the LGB&FR AOC. The largest, contiguous tract of **southern sedge meadow** in the entire LGB&FR AOC is found on the southeastern section of the Malchow/Olson Tract. This sedge meadow has a very low proportional coverage by invasive species, with reed canary grass (*Phalaris arundinacea*) being the most prominent of such species here. Despite being termed a sedge meadow, by far the most abundant species (>85% coverage) is blue-joint grass (*Calamagrostis canadensis*), a tussock-forming grass species. Sedges occur here in much lower abundance (c. 5% coverage), with common tussock sedge (*Carex stricta*) and common lake sedge (*Carex lacustris*) most prominent. Spotted joe-pye-weed (*Eutrochium maculatum*) occurs at a technically rare proportion here but, nevertheless, emerges above the graminoid layer to make a conspicuous show. Although the diversity of forbs is limited in the sedge meadow, the size, relative intactness, and overall rarity of this plant community type in the LGB&FR AOC substantiate it as an area of outstanding ecological significance in the LGB&FR AOC. **Northern mesic forest** can be found in the northcentral section of the property near the hardwood swamps. It consists of a somewhat open canopy of red maple with no woody understory, and has a discontinuous herbaceous layer that mostly consists of Pennsylvania sedge (*Carex pensylvanica*). There is a small, **inland emergent marsh** that is located in the southwestern corner and was recently restored by the Brown County's Land and Water Conservation Department to provide spawning habitat for northern pike[42]. This wetland has reed canary grass, hybrid cattail, swamp milkweed (*Asclepias incarnata*), blue vervain (*Verbena hastata*), and spotted joe-pye-weed (*Eutrochium maculatum*)[3]. There is also some **submergent marsh** in the open water part of the pond[3]. A small wet meadow / **surrogate grassland (old field)** is located in the southern third of the property just west of Dirt Road that is mostly reed canary grass, though many natives are present, including: • Sensitive fern (*Onoclea sensibilis*), moderately common • Blue-joint grass (*Calamagrostis canadensis*), moderately common • Wool grass (*Scirpus cyperinus*), moderately common • Sweet-flag (*Acorus americanus*), rare • Black willow (*Salix nigra*), rare Lastly, there is a very small patch of **Great Lakes barrens** with a sparse canopy of red maple, white pine (*Pinus strobus*), and red oak (*Quercus rubra*) and an open understory of black huckleberry (*Gaylussacia baccata*) and bracken fern (*Pteridium aquilinum var. latiusculum*). Northern oak sedge (*Carex deflexa*) and Pennsylvania sedge (*Carex pensylvanica*) are occasional graminoids here. At the ecotone between the pine barrens and adjacent, red maple swamp forest, grows a tiny and curious plant, the twining screw-stem (*Bartonia paniculata*), which is a WI special concern species that was not known to occur in Brown County prior to UW-Green Bay's plant surveys. The patches of surrogate grassland (old field) and Great Lakes pine barrens are very small and were therefore not digitized or mapped during the 2015 LGB&FR AOC field effort, which is why they are not shown in the habitat map below.
Significant Animals	**Birds**: • Over 200 bird species have been recorded along the west shore in between Oak Ridge Lane and Peters Marsh across all seasons, including[7]:

  - Four state endangered species (Caspian Tern [*Hydroprogne caspia*], Common Tern [*Sterna hirundo*], Forster's Tern [*Sterna forsteri*], and Peregrine Falcon [*Falco peregrinus*])
  - Three state threatened species (Great Egret [*Ardea alba*], Acadian Flycatcher [*Empidonax virescens*], and Cerulean Warbler [*Setophaga cerulea*])
  - Thirty-eight Wisconsin Wildlife Action Plan Species of Greatest Concern (e.g., Brown Thrasher [*Toxostoma rufum*], Canada Warbler [*Cardellina canadensis*])
  - Forty-six state special concern species (e.g., Yellow-billed Cuckoo [*Coccyzus americanus*], Bald Eagle [*Haliaeetus leucocephalus*], Black-throated Blue Warbler [*Setophaga caerulescens*], Purple Martin [*Progne subis*])
  - Seven International Union for Conservation of Nature-listed species as vulnerable (e.g., Rusty Blackbird [*Euphagus carolinus*]) or near threatened (e.g., Golden-winged Warbler [*Vermivora chrysoptera*], Red-headed Woodpecker [*Melanerpes erythrocephalus*])
  - Migratory waterfowl and gulls, including Pied-billed Grebe (*Podilymbus podiceps*) and Bonaparte's Gull (*Chroicocephalus philadelphia*), use offshore waters and emergent marsh; migratory landbirds use the marsh and forest habitats (e.g., Gray-cheeked Thrush [*Catharus minimus*], raptors[37])
  - Although not well documented, several species are known* or expected to breed on the Malchow/Olson Tract, especially marsh and forest birds:
    - Marsh-nesters: Tree Swallow (*Tachycineta bicolor*)*, Purple Martin*, Red-winged Blackbird (*Agelaius phoeniceus*)*, Sedge Wren (*Cistothorus platensis*), Marsh Wren (*Cistothorus palustris*), Virginia Rail (*Rallus limicola*), Swamp Sparrow (*Melospiza georgiana*), and Wilson's Snipe (*Gallinago delicata*)
    - Forest-nesters: American Woodcock (*Scolopax minor*), Hairy Woodpecker (*Picoides villosus*), Northern Flicker (*Colaptes auratus*), and Wood Thrush (*Hylocichla mustelina*)

Fish:

- Twenty-eight fish species have been recorded offshore near the Malchow/Olson Tract and Longtail Point in Dead Horse Bay[9]:
  - Gizzard shad (*Dorosoma cepedianum*)
  - Trout perch (*Percopsis omiscomaycus*)
  - White bass (*Morone chrysops*)
  - Yellow perch (*Perca flavescens*)
  - Sheepshead (*Aplodinotus grunniens*; aka freshwater drum)
  - Walleye (*Sander vitreus*)
  - Spottail shiner (*Notropis hudsonius*)
  - Northern pike, known to migrate from Bay of Green Bay into streams, inlets, or roadside ditch channels along the west shore and spawn in small wetlands; northern pike are extremely common along the southern edge of the Malchow/Olson Tract where they travel in roadside ditches to a recently restored inland wetland in the southwestern corner of this priority area[40,42].
  - Spotted musky (*Esox masquinongy*; aka muskellunge)
  - Banded killifish (*Fundulus diaphanous*), a state special concern species and Wisconsin Wildlife Action Plan Species of Greatest Concern

Mammals:

- Although ~50 mammal species are known to or are expected to occur along the west shore (e.g., American mink [*Neovison vison*], red fox [*Vulpes vulpes*], North

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[9] Wisconsin Department of Natural Resources Fish Trawling Survey Data 1980-2015; sampling points located offshore to south of the Point.

	American river otter [*Lontra canadensis*]; as noted in Roznik 1979)[37], only eastern cottontail (*Sylvilagus floridanus*) has been officially recorded along the west shore in between Oak Ridge Lane and Peters Marsh in recent years. **Anurans**: • Three frog and toad species, which likely breed within the Malchow/Olson Tract, include: o American toad (*Bufo americanus*), eastern gray treefrog (*Hyla versicolor*), and spring peeper (*Pseudacris crucifer*). • Eastern tiger [*Ambystoma tigrinum*] and blue-spotted salamanders [*Ambystoma laterale*] are expected to occur along the west shore of Green Bay (as noted in Roznik 1979)[37], though neither has been officially reported on the Malchow/Olson Tract. **Reptiles**: • Although not well studied, several reptiles are expected to occur along the west shore of Green Bay (as noted in Roznik 1979)[37]: common garter snake [*Thamnophis sirtalis*], eastern snapping turtle [*Chelydra serpentina*], etc.
Habitat Quality	Overall, the ecological quality of the Malchow/Olson Tract is very high, particularly because it contains the best high energy emergent marsh and swamp white oak hardwood swamp found within the whole LGB&FR AOC. These habitats generally have high native plant diversities and relatively few invasive plant species. Invasive plants that are present are typically found along the edges (e.g., reed canary grass) or have been treated by the WDNR (e.g., *Phragmites*)[43]. The Malchow/Olson Tract comprises a natural, relatively undisturbed landscape of emergent marsh that grades into southern sedge meadow, shrub carr, and hardwood swamp; this landscape describes the historical mosaic originally found in lower Green Bay and is fairly uncommon in the LGB&FR AOC[3,4,5]. Plus, this property is relatively undeveloped and has had little to no management or disturbance within the past 100+ years. Parts of the high energy emergent marsh are dominated by soft-stem bulrush and blue-joint grass, two natives that were historically common in lower Green Bay. Along the northcentral and northwestern edges is a red maple hardwood swamp with an herbaceous understory of sensitive fern, royal fern, and juneberries. A green ash hardwood swamp located in the center of the property has an understory of common winterberry; whereas, most forest understories in the LGB&FR AOC are dominated by invasive shrubs (e.g., buckthorn, honeysuckle). Needless to say, the overall high ecological quality of the Malchow/Olson Tract is impressive. Therefore, this property should be protected for fish and wildlife habitat in the LGB&FR AOC in order to maintain sustainable fish and wildlife populations.
Significant Invasive Species Issues	**Invasive Plant Species**: Each of the following species outcompetes and crowds out native plants[4]. Management efforts for invasives at this site are unknown unless otherwise noted. • Common reed (*Phragmites australis*) o *Phragmites* is a common and ongoing problem in the high energy emergent marsh, though recent herbicide sprayings by the WDNR in 2011-2012 and 2015-2016[43] have cut back the amount significantly; it is also present along the edges of the shrub carr; continued efforts to control *Phragmites* is needed. • Hybrid cattail (*Typha × glauca*) o Moderately common in high energy emergent marsh and small inland emergent marsh surrounding the pond in the southwestern corner of the property • Reed canary grass (*Phalaris arundinacea*)

    - Common in high energy and small inland emergent marsh, alder-dominated shrub carr, southern sedge meadow, and surrogate grassland (old field); rare in northern hardwood swamp
- Glossy buckthorn (*Frangula alnus*)
    - Common in some of the hardwood swamp; rare in northern mesic forest and Great Lakes barrens
- European buckthorn (*Rhamnus cathartica*)
    - Rare in hardwood swamp
- Creeping-Charlie (*Glechoma hederacea*)
    - Rare in hardwood swamp and northern mesic forest
- Purple loosestrife (*Lythrum salicaria*)
    - Rare in alder-dominated shrub carr
- Hemp-nettle (*Galeopsis tetrahit*)
    - Rare in northern mesic forest
- Showy bush honeysuckle (*Lonicera* × *bella*)
    - Rare in hardwood swamp
- Japanese barberry (*Berberis thunbergii*)
    - Rare in hardwood swamp
- Eurasian water-milfoil (*Myriophyllum spicatum*)
    - Present and locally common in submergent marshes throughout
- Curly-leaf pondweed (*Potamogeton crispus*)
    - Rare in submergent marsh of unnamed creek

Exotic Plant Species:
- Crack willow (*Salix* × *fragilis*), rare in high energy emergent marsh[4]
- Bittersweet nightshade (*Solanum dulcamara*), rare in high energy emergent marsh and alder-dominated shrub carr[4]

Invasive Animal Species:
- *Birds*
    - European Starling (*Sturnus vulgaris*)[7]
        - Poses some threat to native species, particularly cavity nesters (e.g., Tree Swallow), by outcompeting them and occupying potential nest sites; likely to be found near agricultural fields, housing, and open fields; not currently being managed
    - Brown-headed Cowbird (*Molothrus ater*)[7]
        - May pose a small threat to some native species, particularly those birds that nest in edge habitat (i.e., edge or marsh or woodlot); likely to be found near housing and open fields; not currently being managed
    - House Sparrow (*Passer domesticus*)[7]
        - May pose a small threat to some native species by outcompeting them for food; likely to be found near housing and open fields; not currently being managed
    - Other exotic bird species are likely occur at the Malchow/Olson Tract, notably Ring-necked Pheasant (*Phasianus colchicus*) and Rock Pigeon (*Columba livia*); however, these species generally do not significantly affect native birds because they typically inhabit human areas (e.g., developed or agricultural areas)[7]
    - Mute Swans (*Cygnus olor*) are also likely to occur offshore and may pose a small threat to submergent marsh because they are known to eat submerged plants faster than the plants can regrow[7,10]

- *Fish*: Recorded offshore southeast of the Malchow/Olson Tract in open water in Dead Horse Bay[9].

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[10] Mute Swan by the Cornell Lab of Ornithology. Available: https://www.allaboutbirds.org/guide/Mute_Swan/lifehistory (accessed on 28 Oct 2016).

	o Alewife (*Alosa pseudoharengus*)[11] ▪ Poses a threat to native fish species by consuming zooplankton and disturbing the natural food web; not currently being managed o Common carp (*Cyprinus carpio*)[12] ▪ Destroy vegetation by uprooting plants and increasing cloudiness of water; not currently being managed o Rainbow smelt (*Osmerus mordax*)[13] ▪ Negatively affect uncommon to rare native fish species; not currently being managed o Round goby (*Neogobius melanostomus*)[14] ▪ Prey on small native fish and eggs (e.g., darters) and outcompete similarly sized native fish; not currently being managed o White perch (*Morone americana*)[15] ▪ Prey on native fish eggs, such as walleye; not currently being managed
Management and Restoration Recommendations	• Continue controlling for invasive plants, such as *Phragmites*, reed canary grass, and woody plants (e.g., buckthorn) in all major habitats as needed. • Investigate reintroducing wild rice (*Zizania* spp.) near the mouth of the small stream on the south side of the property where it was known to occur in 1840 (see “Site History” below). • Develop or restore important fish spawning and nursery habitats, such as rocky reefs, gravel, cobble, woody debris, and sandy areas for shoreline fish. • Continue efforts to maintain northern pike passage along migratory corridors on the southern side of this priority area and the restored wetland for spawning. • Expand existing southern sedge meadow. • Along and within the stream, improve substrate (including gravel, riffles, and pool habitat) and protect/enhance riparian habitats. • Designate and protect sensitive areas and investigate establishing a conservation easement. • Protect, maintain, and expand submergent marsh biodiversity hotspots. • 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. • Conduct baseline studies on wildlife that have not been adequately sampled here: aquatic invertebrates (e.g., dragonflies, mayflies), reptiles, and mammals.
Reference Links and Documents	**Links**: • Fox 11 new story on the northern pike restoration project. Available: http://fox11online.com/news/local/newborn-northern-pike-head-for-home.

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[11] 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.

[12] 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.

[13] 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.

[14] 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.

[15] 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.

	Reference Documents: - Dorney, J.R. 1975 The vegetation pattern around Green Bay in the 1840s as related to geology, soils, and land use by Indians with a detailed look at the Townships of Scott, Green Bay, and Suamico. Book available through the UW-Green Bay Cofrin Library Archives and Area Research Center. - Wisconsin Department of Natural Resources. 1979. Green Bay West Shores Master Plan Concept Element. Property Task Force: F. Roznik, J. Raber, D. Olson, L. Lintereur, and L. Kernen.
Site History (e.g., original vegetation, past conservation projects)	In the early 1630s, Frenchman Jean Nicolet first arrived in lower Green Bay when it was primarily inhabited by Native American tribes[16]. Lower Green Bay consisted of large beds of wild rice (*Zizania* sp.) and wild celery (*Vallisneria americana*), extensive emergent marsh (*Schoenoplectus* sp., cattail), sedge meadows (*Calamagrostis canadensis*), shrub carr (e.g., *Cornus* spp., *Salix* spp.), swamps, and wet conifer forest (black spruce [*Picea mariana*], balsam fir [*Abies balsamea*])[17,18,19,20,21,22]. Between the late 1600s and 1800s, European fur trade, duck hunting, fishing, logging, shipping, and agriculture were important early industries in lower Green Bay[23,24,25]. In the early 1800s, there were a few small settlements and farms of Europeans and Native Americans in the lower Bay[24]. Menominee people were likely the predominant Native American tribe residing in the Village of Suamico prior to and during European settlement[27]. In late August and September 1840, surveyors of the Wisconsin Public Land Survey System (PLSS) noted that along the coastal area of the Malchow/Olson Tract there was a shallow marsh consisting of wild rice and rushes (*Juncus* spp.) that was located near the mouth of the small stream on the south side of the property (stream is still present today and connects to the ponds at Barkhausen Waterfowl Preserve) as well as a tamarack (*Larix laricina*) swamp[26]. Further inland about a half kilometer, there were oak (recorded as "S. oak," which is likely swamp white oak) and aspen (*Populus tremuloides*) forests[26]. Similarly, Dorney (1975) reported that most of this property consisted of tamarack (*Larix laricina*), black ash (*Fraxinus nigra*), and alder (*Alnus incana*) as well as marsh (called "swamp" in Dorney 1975)[27]. The Malchow/Olson Tract is currently located in what is today called the Village of Suamico. Suamico was founded in August 1848, and the primary source of income for residents was from farming or working at large sawmills in the 1850s and 1860s[28].

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[16] Jean Nicolet: French Explorer. By The Editors of Encyclopaedia Britannica. Available: https://www.britannica.com/biography/Jean-Nicolet (accessed on 24 Oct 2016).

[17] Arthur C. Neville's Map of Historic Sites on Green Bay, Wisconsin 1669-1689. Available: http://s3.amazonaws.com/labaye/data/Bay%20Settle ment%20Map%20WI%20Historical%20Bulletin%201926.pdf (accessed on 24 Oct 2016).

[18] 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).

[19] 1845 Chart of Green Bay. Available http://s3.amazonaws.com/labaye/data/1845%20Chart%20of%20Green%20Bay.pdf (accessed on 24 Oct 2016).

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

[21] UW-Green Bay personal communication with Thomas Erdman.

[22] 1845 Map of western lower Green Bay. Available: http://browncounty.maps.arcgis.com/apps/StorytellingSwipe/index.html?appid=72615351 ef33434e9a6a1bb5fffdbe9c&webmap=02074b6abfc44b88bfe9e96afe90a014 (accessed on 28 Oct 2016).

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

[24] 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).

[25] 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).

[26] Wisconsin Public Land Survey System (1834) from file "PLSS_SurveyData.shp"

[27] The vegetation pattern around Green Bay in the 1840s as related to geology, soils, and land use by Indians with a detailed look at the Townships of Scott, Green Bay, and Suamico by John Dorney, 1975. File "Dorney1975_VegetationPatternGreenBay1840s.pdf".

[28] Suamico Information and Photos from the Howard-Suamico Historical Society. Available: http://www.hshistoricalsociety.org/Suamico.html (accessed on 26 Oct 2016).

Throughout the 1800s and early 1900s, European immigrants sailed across the Atlantic Ocean to reach the United States in order to escape difficult economic and social times of Europe[29]. Immigrants arriving in the state of Wisconsin were largely German though others included Irish, Norwegian, Dutch, and Canadian[29]. Dating back to 1875, the Malchow/Olson Tract was privately owned by U. H. Peak[30], and in 1889, it was owned by A. McDonald[31]. Sometime in the (estimated) 1890s, the Malchow family (likely the parents of the now deceased children, William and Gordon Malchow) immigrated from Germany and settled on the priority area currently known as “Malchow/Olson Tract”[32]. They owned most of this land and used it primarily for farming as did many Suamico residents[32]. The original Malchow’s had two sons, William Malchow (born c1899) and Gordon Malchow (born 1901)[33,34]. Gordon Malchow married Ethel Malchow (maiden name unknown; born c1912), and they had eleven children (including Edmund [born 1925], Vernon [born c1936], Eileen Malchow [born c1937], and others)[32,33]. In the 1935 Plat book, it was documented that William Malchow owned the same property described here on the Malchow/Olson Tract[35]. Eileen Malchow married Gordon (“Gordy”) Olson, and they had three children [Jan, Bert, and Julie Malchow])[36]. Many of Gordon and Ethel Malchow’s children (including Eileen Olson [formerly Malchow]) and extended family still own and live on their family’s land today[32]. Before Gordon and Ethel Malchow died, their one wish was for their children to preserve this family property for the purposes of wildlife preservation rather than selling the land for development[32]. Thanks to Eileen and her siblings’ perseverance in honoring their parent’s wishes, most of this ecologically important tract of land is largely untouched. It is relatively intact and contains significant, high quality fish and wildlife habitat that is critical to the LGB&FR AOC. In fact, the high energy emergent marsh and hardwood forest represent the best and highest quality habitats in the entire LGB&FR AOC.

In the late 1970s, the WDNR published a master plan, in which they delineated habitat types for west shore wildlife areas, including the Malchow/Olson Tract even though it is privately owned[37]. Interestingly, the habitat types from the 1970s look very similar to what UW-Green Bay found in 2015-16 when they conducted a habitat mapping across the LGB&FR AOC (2015) and detailed vegetation surveys (2016)[3,4,37]. In the 1970s, the Malchow/Olson Tract consisted of a band of “emergent vegetation” along the shoreline with plants like cattail, bulrush, and tall sedges[37]. The next band of habitat further inland was “lowland brush willow,” which contained at least 50% willow[37]. In the northwestern corner of the property was “northern hardwoods” with sugar maple (*Acer saccharum*), basswood (*Tilia americana*), yellow birch (*Betula alleghaniensis*), and elm (*Ulmus americana*)[37]. Along most of the western edge of the property was swamp hardwood forest with black ash, American elm, black willow (*Salix nigra*), and some cottonwood (*Populus deltoides*)[37]. There were also small grassy openings in the southwestern corner and southern third of the property and an oak-dominated wooded area in the southwestern corner[37]. Based on a 1970 survey by George Howlett, there was also a submergent marsh with coon’s tail (*Ceratophyllum demersum*), sago pondweed (*Stuckenia pectinata*), and common duckweed (*Lemna minor*) as dominants[38]. Other important natives found there included: blue-joint grass, greater straw sedge (*Carex normalis*), woollyfruit sedge (*Carex lasiocarpa*), flat sedge

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[29] 19th Century Immigration by the Wisconsin Historical Society. Available: http://www.wisconsinhistory.org/turningpoints/tp-018/?action=more_essay (accessed on 25 Oct 2016).

[30] 1875 Brown County plat map. Available through the UW-Green Bay Cofrin Library Archives and Area Research Center.

[31] 1889 Brown County plat map. Available through the UW-Green Bay Cofrin Library Archives and Area Research Center.

[32] UW-Green Bay personal communication with Eileen Olson (formerly Malchow).

[33] Ancestry.com Records on Gordon Malchow from the 1940 Census. Available: http://www.ancestry.com/1940-census/usa/Wisconsin/Gordon-Malchow_2znsq1 (accessed on 25 Oct 2016).

[34] People Search on Malchow. Available: http://www.locateancestors.com/malchow-wisconsin/ (accessed on 25 Oct 2016).

[35] 1935 Plat Book of Suamico, WI: http://www.gis.co.brown.wi.us/web_documents/LIO/HistoricMaps/PorathPlatBook1934-1936/Town%20of% 20Suamico%20Jan%201935.pdf.

[36] Gordon L. Olson’s Obituary. Available: http://www.lyndahl.com/obituary/73513/Gordon-L-%22Gordy%22-Olson/ (accessed on 25 Oct 2016).

[37] Green Bay West Shores Master Plan Concept Element 1979 by Roznik et al.

[38] Howlett, Jr. 1974: The rooted vegetation of west Green Bay with reference to environmental change

(*Cyperus odoratus*), bald spike-rush (*Eleocharis calva*), boneset (*Eupatorium perfoliatum*), common rush (*Juncus effusus*), and curly-top knotweed (*Persicaria lapathifolia*)[38].

Some of the property has agricultural fields and small housing areas that have likely been there for >100 years (anthropogenic land use visible in 1938 air photo)[39]. Based on a site visit in July 2016, it also appears that some of the northern mesic forest on the northcentral part of the property was cut sometime in the past ten years since there are many old tree stumps[4]. Otherwise, the Malchow/Olson Tract has been relatively unaffected by disturbance and management through the years. However, it should be noted that the Wisconsin Department of Natural Resources (WDNR) recently launched two major herbicide sprayings of *Phragmites* along the west shore[43]. One of the many sites included in this effort was the Malchow/Olson Tract. In 2011 and 2012, the WDNR conducted an aerial herbicide spraying along the entire coastal area of the Malchow/Olson Tract (or approximately one third of the total area of the tract) in 2011 and 2012. Then, they did a small, follow-up ground treatment of approximately 11 ha of the coastal area as well as a small inland wetland in 2015 and 2016. These management efforts were huge successes on this property because the amount of *Phragmites* present today has been significantly reduced.

Since 2013, Brown County's Land and Water Conservation Department has led a northern pike habitat restoration project along the west shore (including the Malchow/Olson Tract), in which the goal of the project was to establish riparian buffers, remove stream impediments to fish migration, and restore wetland areas along intermittent and perennial streams[40]. Northern pike are known to migrate along roadside ditches, such as Lineville Road (southern boundary of Malchow/Olson Tract in Suamico, WI), to their inland spawning grounds[40]. Pike spawn in the small restored wetland on the Malchow/Olson Tract in the spring, and then both the adults and young-of-the-year emigrate back to the Bay of Green Bay[40]. The Brown County Land and Water Conservation Department, WDNR, and UW-Green Bay have conducted northern pike studies on the Malchow/Olson Tract and elsewhere across the west shore of the Bay; some studies date back to 1996[40].

Eileen and her family have been instrumental, welcoming, and kind in helping local conservation efforts that have taken place on their family's property over the years. Local efforts conducted on their property include those organized by: University of Wisconsin-Green Bay's Cofrin Center for Biodiversity (information provided by Eileen in this narrative; granting permission to survey birds and frogs in 2014, habitats in 2015, and plants in 2016 [including collecting plant specimens from their property for herbarium archives]), Brown County's Land and Water Conservation Department (northern pike west shore restoration project over the past several years have taken place on the Malchow/Olson property and other local land owners[41,42]), and Wisconsin Department of Natural Resources (aerial herbicide treatment of *Phragmites* in 2011-2012 and on the ground in 2015-2016 on the Malchow property and others[43]). **These organizations and agencies extend their sincere gratitude and appreciation to the Malchow family**.

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[39] Brown County's Multi-purpose GIS map and 1938 aerial photograph. Available: http://www.co.brown.wi.us/departments/page_7f0c2fbe_6bc6/?department=85713eda4cdc&subdepartment=89ce08984445 (accessed on 2 Nov 2016).

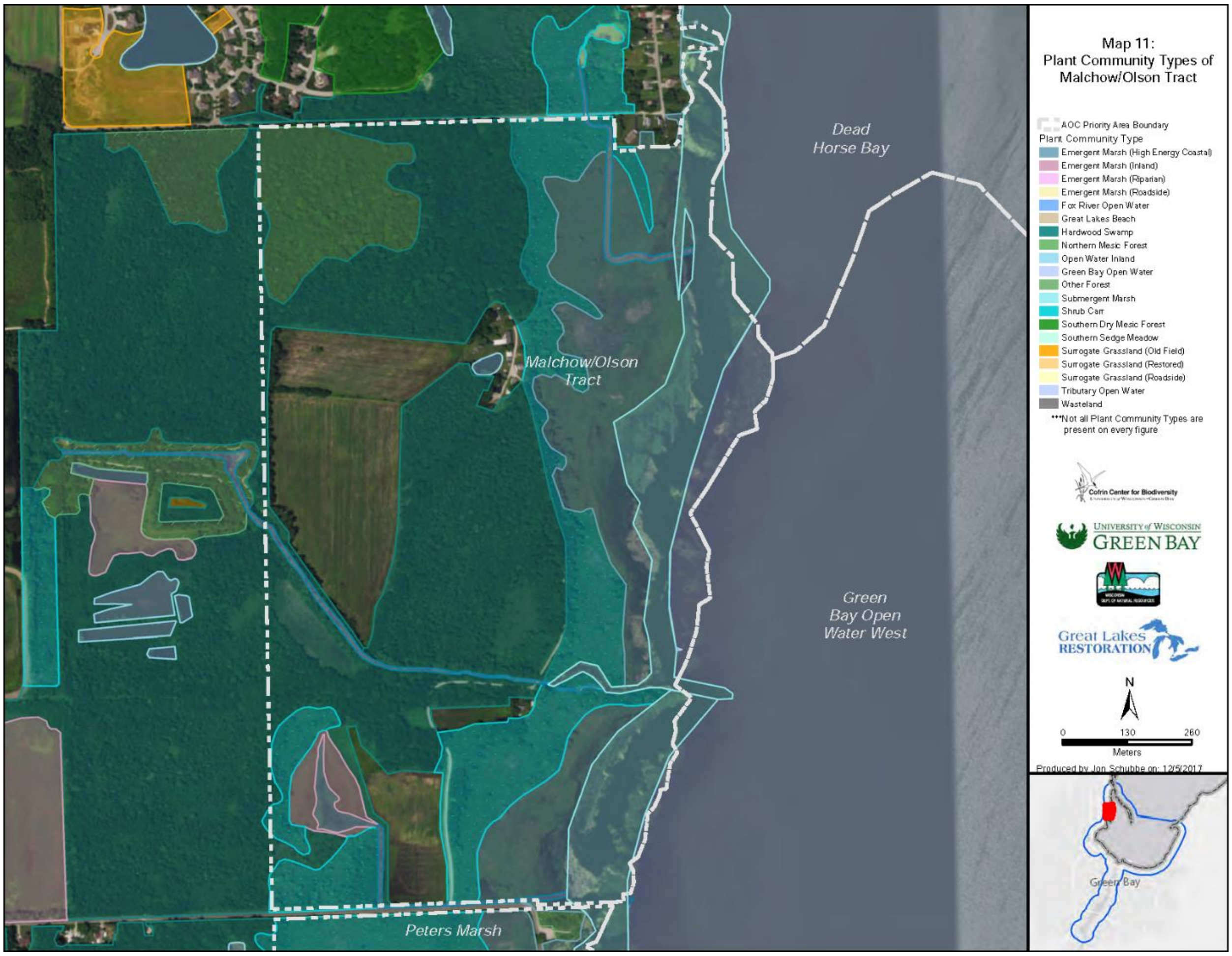
[40] LGB&FR AOC Comprehensive Conservation Project Catalogue

[41] Fox 11 new story on the northern pike restoration project. Available: http://fox11online.com/news/local/newborn-northern-pike-head-for-home (accessed on 25 Oct 2016).

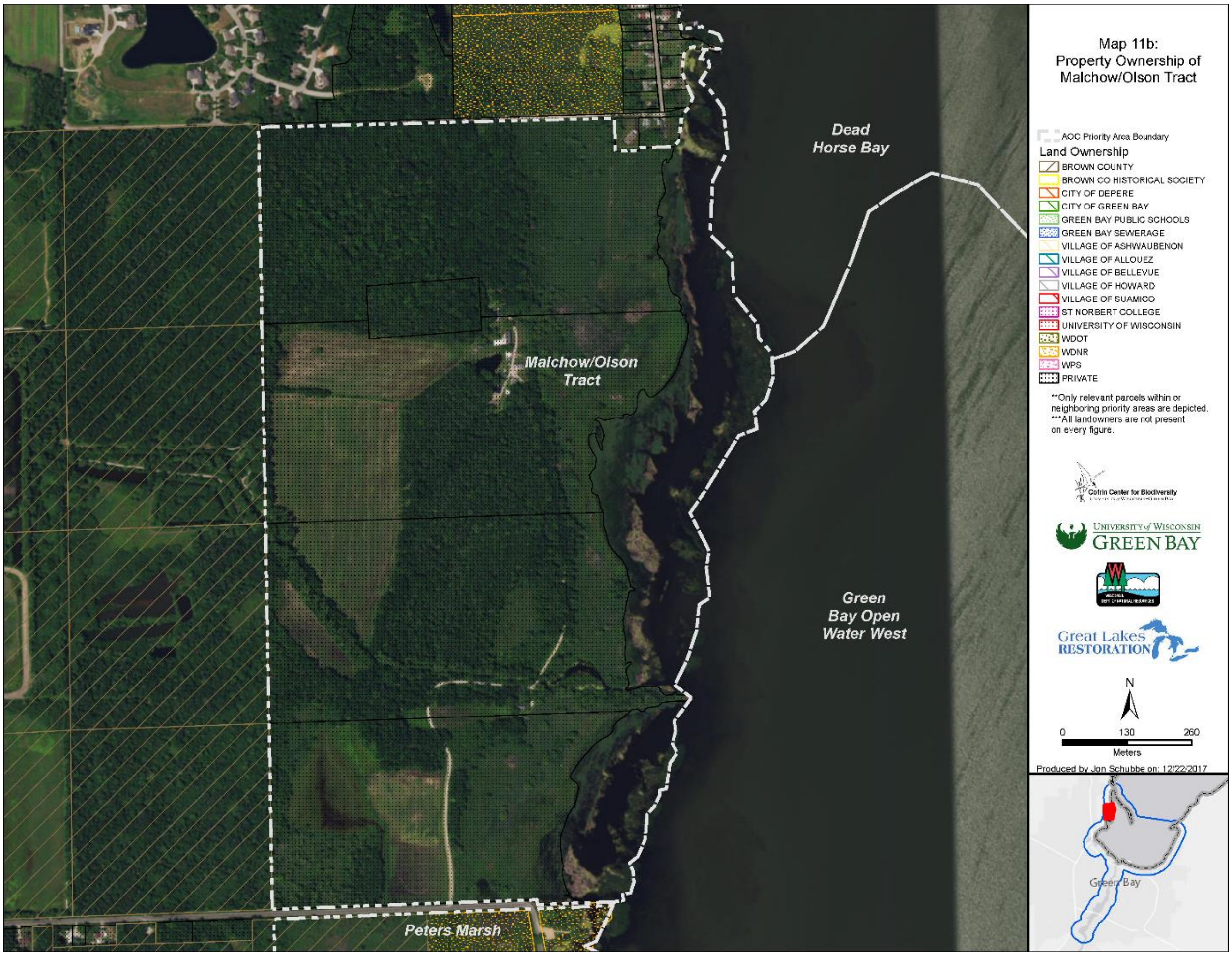
[42] Brown County West Shore Northern Pike Habitat Project: http://www.co.brown.wi.us/departments/page_f2f42ba8553c/?department=097_c0e79486a&subdepartment=7c17181709a3 (accessed on 25 Oct 2016).

[43] WI Dept. of Natural Resources' Phragmites Treatment 2011-12 and 2015-16. Files "GLFWRA_Phrag2015_16_aoc.shp" and "Aerial_2011_12.shp".

Map of the Malchow/Olson Tract's 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.



Land ownership boundaries of the Malchow/Olson Tract. Map made by UW-Green Bay’s Jon Schubbe.



Photograph of the Malchow/Olson Tract facing directly west. Photograph taken by Erin Giese on 2 December 2016.

Appendix 10.10: Peters Marsh

Written by Erin Giese and James Horn

<table>
<tr><td>Location (centroid)</td><td>Lat. 44.584690°, Lon. -88.019994°[1] (NAD 1983, UTM Zone 16N)</td></tr>
<tr><td>Total Area (ha)</td><td>106.63 ha</td></tr>
<tr><td>Area Public Land (ha)</td><td>94.37 ha</td></tr>
<tr><td>Area of Habitat Types Present (ha) and Percent of Each Habitat Type</td><td>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&FR AOC)[3]. Habitat types within Peters Marsh 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 104.25 ha of natural habitat within Peters Marsh.
<table>
<tr><th>Habitat Type</th><th>Area (ha)</th><th>Percent</th></tr>
<tr><td>Emergent Marsh (High Energy Coastal)</td><td>50.76</td><td>48.69</td></tr>
<tr><td>Hardwood Swamp</td><td>0.84</td><td>0.81</td></tr>
<tr><td>Other Forest</td><td>0.48</td><td>0.46</td></tr>
<tr><td>Shrub Carr</td><td>11.31</td><td>10.85</td></tr>
<tr><td>Submergent Marsh</td><td>39.4</td><td>37.79</td></tr>
<tr><td>Surrogate Grassland (Old Field)</td><td>0.46</td><td>0.44</td></tr>
<tr><td>Tributary Open Water</td><td>1</td><td>0.96</td></tr>
</table>
<i>Disclaimer!</i> <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 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 of 2016 and 2017. Great Lakes water levels were much higher in 2016 and 2017 than in July 2015.</i></td></tr>
<tr><td>General Description</td><td>Peters Marsh is a relatively large priority area located along the west shore of the bay of Green Bay just south of Lineville Road that is almost entirely publicly owned by Brown County and the Wisconsin Department of Natural Resources. Its eastern border is protected from wave action by Bayshore Drive and the Cat Island Wave Barrier (fully constructed in 2013), though the southern part of the marsh is open and exposed to the bay, seiche, and wave action. Like much of the west shore, it primarily consists of Roscommon muck and Tedrow loamy fine sand soils[2]. Depending on lake levels, it is primarily dominated by emergent and submergent marsh that naturally grades into shrub carr[3,4,5]. Unfortunately, most of the emergent marsh is dominated by a monoculture of the invasive hybrid cattail (<i>Typha × glauca</i>), common reed (<i>Phragmites australis</i>; hereafter referred to as "<i>Phragmites</i>"), and reed canary grass (<i>Phalaris arundinacea</i>), quite unlike the historical assemblage of native plants that formerly were dominants, which includes sedges, wild rice (<i>Zizania aquatica</i>), wild celery (<i>Vallisneria</i></td></tr>
</table>

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[1] File "AOC_PriorityAreas.v09_20171212.shp"

[2] Soil Survey Geographic (SSURGO) by the United States Department of Agriculture's Natural Resources Conservation Service. Published Dec 2010. Available: http://uwgb.maps.arcgis.com/home/item.html?id=204d94c9b1374de9a21574c9efa31164; accessed 1 Nov 2016.

[3] LGB&FR AOC 2015 habitat field mapping effort

[4] LGB&FR AOC 2017 submerged aquatic vegetation (SAV) field surveys

[5] Kupsky and Dornbush 2017 report: file "Final Report.pdf" for Kupsky's UW-Green Bay thesis

	americana), and cattails (*Typha latifolia*)[6,7]. Despite its current extremely low native plant diversity, it provides critical habitat for muskrats, anurans (frogs + toads), breeding and migratory marshbirds, waterfowl, fish, and insects[7,8].
Special Features	• Important habitat for muskrats in the emergent marsh[8]. • Significant breeding habitat for many marsh-nesting bird species[8] and migratory habitat for waterfowl and songbirds[8,9]. • Important habitat for many fish species in the submergent and emergent marshes[8].
Natural Habitat Communities and Significant Plants[3,4,5] (ordered in terms of ecological importance and size/amount)	Nearly half of Peters Marsh consists of **emergent marsh (high energy coastal)**, which is found across much of this priority area's boundary, including the center. A small **tributary** traverses through this marsh and runs north/south. Other small patches of emergent marsh (high energy coastal) are found along the eastern edge of this priority area amongst houses facing the bay of Green Bay. The main section of this marsh in the middle of the priority area is largely dominated by hybrid cattail, *Phragmites*, and reed canary grass. Vervain (*Verbena hastata*), spotted joe-pye-weed (*Eutrochium maculatum*), goldenrod (*Solidago* spp.), and European marsh thistle (*Cirsium palustre*) have also been reported here. During higher lake levels, there are usually large pockets of open water in between the plants. Native plants include: • Blue-joint grass (*Calamagrostis canadensis*), rare • Bulbet water-hemlock (*Cicuta bulbifera*), rare • Swamp milkweed (*Asclepias incarnata*), rare • River bulrush (*Bolboschoenus fluviatilis*), rare • Common lake sedge (*Carex lacustris*), rare • Narrow-leaved hedge-nettle (*Stachys tenuifolia*), rare • Softstem bulrush (*Schoenoplectus tabernaemontani*), common locally • Giant burr-reed (*Sparganium eurycarpum*), common locally Along the southern edge of Peters Marsh is **submergent marsh**, the second most common habitat type that makes up almost 38% of the total area. Natives include: • Coon's-tail (*Ceratophyllum demersum*), common • Perennial duckweed (*Lemna turionifera*) • Giant duckweed (*Spirodela polyrrhiza*) • Leafy pondweed (*Potamogeton foliosus*), moderately common • Canada waterweed (*Elodea canadensis*), common locally • Sago pondweed (*Stuckenia pectinata*), common locally • Common bladderwort (*Utricularia vulgaris*), moderately common • Arum-leaved arrowhead (*Sagittaria cuneata*), moderately common Pockets of **shrub carr** are located in the northwestern corner of Peters Marsh with a few small patches in the southwestern section, making up nearly 11% of total habitat area. The shrub carr largely consists of willow (*Salix* spp.), though dogwood (*Cornus* sp.) and buckthorn (family Rhamnaceae) have also been recently reported. Along the eastern edge of Bayshore Drive are private homes with pockets of **hardwood swamp**, **surrogate grassland (old field)**, and **other forest**, which constitute <2% of Peters Marsh's natural habitats.
Significant Animals	**Birds**: • Over 200 bird species have been recorded along parts of the west shore, including[8]:

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[6] Matthes 1976: A recreation plan for the west shore wildlands
[7] McLaughlin & Harris 1990: Aquatic insect emergence in two Great Lakes marshes
[8] LGB&FR AOC comprehensive biota database: file "AOCBiota_DB_ShareableVersion_20171210.accdb"
[9] LGB&FR AOC 2016-17 Waterfowl Surveys by Tom Prestby

  - Four state endangered species (Caspian Tern [*Hydroprogne caspia*], Common Tern [*Sterna hirundo*], Forster's Tern [*Sterna forsteri*], and Peregrine Falcon [*Falco peregrinus*])
  - Four state threatened species (Great Egret [*Ardea alba*], Acadian Flycatcher [*Empidonax virescens*], Yellow-crowned Night-Heron (*Nyctanassa violacea*), and Cerulean Warbler [*Setophaga cerulea*])
  - Forty-one Wisconsin Wildlife Action Plan Species of Greatest Concern (e.g., Brown Thrasher [*Toxostoma rufum*], Canada Warbler [*Cardellina canadensis*])
  - Forty-two state special concern species (e.g., Yellow-billed Cuckoo [*Coccyzus americanus*], Bald Eagle [*Haliaeetus leucocephalus*], Black-throated Blue Warbler [*Setophaga caerulescens*], Purple Martin [*Progne subis*])
  - Seven International Union for Conservation of Nature-listed species as "vulnerable" (e.g., Rusty Blackbird [*Euphagus carolinus*]) or "near threatened" (e.g., Golden-winged Warbler [*Vermivora chrysoptera*], Red-headed Woodpecker [*Melanerpes erythrocephalus*])
  - Migratory waterfowl and gulls, including scaup, mergansers, Redhead (*Aythya americana*), teal, Ring-necked Duck (*Aythya collaris*), Ruddy Duck (*Oxyura jamaicensis*), grebes, and others
- Despite the emergent marsh's lack of native plant diversity, it provides critical nesting habitat for many marsh- (and sometimes secretive) breeding birds, although the presence of some of these species depends on lake levels[10]:
  - Common Gallinule (*Gallinula galeata*)
  - American Coot (*Fulica americana*)
  - Least Bittern (*Ixobrychus exilis*)
  - American Bittern (*Botaurus lentiginosus*)
  - Pied-billed Grebe (*Podilymbus podiceps*)
  - Marsh Wren (*Cistothorus palustris*)
  - Virginia Rail (*Rallus limicola*)
  - Sora (*Porzana carolina*)
  - Swamp Sparrow (*Melospiza georgiana*)
  - Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*)
  - Red-winged Blackbird (*Agelaius phoeniceus*)
  - Green Heron (*Butorides virescens*)
  - Common Yellowthroat (*Geothlypis trichas*)
  - Yellow Warbler (*Setophaga petechia*)

Fish:

- Although >80 fish species have been recorded in the pelagic zone of the lower bay, some of which may use Peters Marsh, only one official record is available at this time, namely the invasive common carp (*Cyprinus carpio*), which has also been recorded spawning in Peters Marsh[5]. Other species that use the bay, include:
  - 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): redside dace (*Clinostomus elongatus*) and lake sturgeon (*Acipenser fulvescens*)

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[10] WI Breeding Bird Atlas II Project – data available here: http://ebird.org/ebird/atlaswi/explore

	Mammals: • Although ~50 mammal species are known or are expected to occur along the west shore (e.g., American mink [*Neovison vison*], red fox [*Vulpes vulpes*], North American river otter [*Lontra canadensis*]; as noted in Roznik 1979)[11], only muskrat (*Ondatra zibethicus*), coyote (*Canis latrans*), and eastern chipmunk (*Tamias striatus*) have been officially recorded along the west shore in the southwestern corner. **Anurans**: • Six anuran (frog/toad) species[8,12]: o American toad (*Bufo americanus*), eastern gray treefrog (*Hyla versicolor*), green frog (*Lithobates clamitans*), northern leopard frog (*Lithobates pipiens*), spring peeper (*Pseudacris crucifer*), and wood frog (*Lithobates sylvaticus*) o Northern leopard frog is both a federal and state species of special concern **Arthropods**: • Many different spider species have also been recorded along the southwestern corner of Green Bay's wests shore, including *Tmeticus ornatus*, *Tetragnatha caudate*, and *Larinioides cornutus*[8].
Habitat Quality	Unfortunately, most of the emergent marsh is dominated by a monoculture of the invasive, hybrid cattail (*Typha* × *glauca*), common reed (*Phragmites australis*), and reed canary grass (*Phalaris arundinacea*), quite unlike the historical assemblage of native plants it once included.
Significant Invasive Species Issues	**Invasive Plant Species**: Each of the following species outcompetes and crowds out native plants. Recent herbicide sprayings primarily targeting common reed have been conducted by the WDNR in 2011-2012 throughout the emergent high energy marsh.[13] Then, in 2015-2016, Bay-Lake Regional Planning Commission did some follow up herbicide application in Peters Marsh in 2015 along the southwestern edge of the emergent high energy marsh close to shrub carr.[14] • Hybrid cattail (*Typha* × *glauca*) o Extremely common and widespread in high energy emergent marsh. Outcompetes native species and has developed into a monoculture. • Common reed (*Phragmites australis*) o *Phragmites* is still an ongoing problem in the high energy emergent marsh, though not nearly as difficult as the hybrid cattail. Recent herbicide sprayings have helped to cut back the amount significantly. • Reed canary grass (*Phalaris arundinacea*) o Common in the more upland, northern parts of the emergent high energy marsh. • Eurasian water-milfoil (*Myriophyllum spicatum*) o Relatively uncommon to rare in submergent marsh along the easternmost border of Peters Marsh near houses. **Invasive Animal Species**: • *Birds* o European Starling (*Sturnus vulgaris*)[8] ▪ Poses some threat to native species, particularly cavity nesters (e.g., Tree Swallow), by outcompeting them and occupying

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[11] Green Bay West Shores Master Plan Concept Element 1979 by Roznik et al.

[12] Anuran surveys from 2016-17 Great Lakes Coastal Wetland Monitoring Program, per Erin Giese

[13] WDNR Phragmites treatment shapefile: "Aerial.shp"

[14] Bay-Lake Regional Planning Commission Phragmites treatment shapefile: "GLFWRA_Phrag2015_16_aoc.shp"

	potential nest sites; likely to be found near agricultural fields, housing, and open fields; not currently being managed. ○ Exotic bird species, Ring-necked Pheasant (*Phasianus colchicus*), has been recorded in the southwestern corner of the west shore in lower Green Bay; however, it generally does not significantly affect native birds because they typically inhabit human areas (e.g., developed or agricultural areas)[8]. • *Fish* ○ Common carp (*Cyprinus carpio*)[5] ▪ Destroy vegetation by uprooting plants and increasing cloudiness of water; not currently being managed[15].
Management and Restoration Recommendations	• Control invasive plant species (e.g., *Phragmites*, hybrid cattail) and maintain an appropriate mix of open water native emergent vegetation in west shore marshes. • Create nest structures for Black Tern (*Chlidonias niger*) and Forster's Tern. • Establish safe road crossings at strategic areas for anurans and turtles. • Continue investigating the re-establishment of wild celery and wild rice in the submergent marsh by determining substrate needs for target plant species and then enhance and restore substrate condition. • Improve and maintain a high quality, native mix of submergent and emergent plants. • Maintain sustainable populations of muskrat. • Establish safe road crossings at strategic areas for anurans and turtles. • Conduct aquatic invertebrate baseline study and continue investigating the possibility of reintroducing mayflies (e.g., *Hexagenia* sp.).
Reference Links and Documents	**Links**: • Topographic Map of Peters Marsh: https://www.topozone.com/wisconsin/brown-wi/swamp/peters-marsh/ **Reference Documents**: • Dorney, J.R. 1975 The vegetation pattern around Green Bay in the 1840s as related to geology, soils, and land use by Indians with a detailed look at the Townships of Scott, Green Bay, and Suamico. Book available through the UW-Green Bay Cofrin Library Archives and Area Research Center. • Draney, M. L., and Jaskula, J. M. 2004. Araneae and Opiliones from Typha spp. and *Phragmites australis* stands of Green Bay, Lake Michigan, and an exotic spider species newly reported from the U.S. Great Lakes region. The Great Lakes Entomologist 37(3-4):159-164. • Harris, H. J. and R. S. Cook. 1973. Preimpoundment baseline studies of the Peters Marsh Wildlife Area. Preliminary report. • Herdendorf, C. E., S. M. Hartley, and M. D. Barnes. 1981. Fish and wildlife resources of the Great Lakes coastal wetlands within the United States. FWS/OBS-81/02. U.S. Fish and Wildlife Service Technical Report 5(3), 383 pp. • Kupsky, B. and M. Dornbush. 2017. Cat Island and Duck Creek Delta Restoration: Restoring Green Bay Aquatic Vegetation Final Report. Final report submitted to Ducks Unlimited in January 2017. • Matthes, L. R. 1976. A recreation plan for the west shore wildlands. Report. 84 pp. • McLaughlin, D. B. and H. J. Harris. 1990. Aquatic insect emergence in two Great Lakes marshes. Wetlands Ecology and Management 1(2):111-121. • Roznik, F. D. 1978. Response of the Yellow-headed Blackbird to vegetation and water level changes in coastal marshes of Green Bay. Thesis. University of Wisconsin-Green Bay, Green Bay, Wisconsin.

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[15] 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.

Site History (e.g., original vegetation, past conservation projects)	In the early 1630s, Frenchman Jean Nicolet first arrived in lower Green Bay when it was primarily inhabited by Native American tribes[16]. Lower Green Bay consisted of large beds of wild rice (*Zizania* sp.) and wild celery (*Vallisneria americana*), extensive emergent marsh (*Schoenoplectus* sp., cattail), sedge meadows (*Calamagrostis canadensis*), shrub carr (e.g., *Cornus* spp., *Salix* spp.), swamps, and wet conifer forest (black spruce [*Picea mariana*], balsam fir [*Abies balsamea*])[17,18,19,20,21,22]. Between the late 1600s and 1800s, European fur trade, duck hunting, fishing, logging, shipping, and agriculture were important early industries in lower Green Bay[23,24,25]. In the early 1800s, there were a few small settlements and farms of Europeans and Native Americans in the lower bay[24]. In late August and September 1840, surveyors of the Wisconsin Public Land Survey System (PLSS) noted that along the coastal area close to Peters Marsh there were natural, wet meadows with neighboring areas of tamarack (*Larix laricina*) and oak (*Quercus* sp.)[26]. Similarly, Dorney (1975) reported that parts of Peters Marsh consisted of tamarack (*Larix laricina*) as well as neighboring grassy marshes[27]. According to other sources, sedges, wild rice, wild celery, and cattails were found in Peters Marsh with the vegetation varying of course due to lake levels[6,7]. By the mid-1970s, the wild rice and wild celery beds were gone[6], largely due to carp, which are known to destroy plants by uprooting them as well as declining water quality in Green Bay[28]. However, sedges, grasses, and shrub carr still remained[6,29]. The bands of shrub carr of Peters Marsh were dominated by willow (*Salix* sp.) along the middle/center and tag alder (*Alnus incana*) along the far western edge[6]. The Arnold Otto Peters family owned most of the present day Peters Marsh with the exception of the land east of Bayshore Drive, which was owned by Elmer Dickinson, Alton Van Gemert, Serena Salscheider, and Peaks Rite Retrievers Club (ownership based on old paper property map with no date). Eventually, the Fort Howard Foundation owned most of the property but ultimately donated the land to Brown County in the early 1970s[31]. A few years later, the state of Wisconsin acquired part of Peters Marsh starting in December 1978[31]. Today, the Otto Peters family still owns a small parcel on the east side of Bayshore Drive, while the bulk of the marsh is owned by Brown County and to a lesser extent by the WDNR. According to a study conducted in the early 1970s, Peters Marsh provided critical breeding habitat for many bird species, some of which are rare or gone today, including

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[16] Jean Nicolet: French Explorer. By The Editors of Encyclopaedia Britannica. Available: https://www.britannica.com/biography/Jean-Nicolet (accessed on 24 Oct 2016).

[17] Arthur C. Neville's Map of Historic Sites on Green Bay, Wisconsin 1669-1689. Available: http://s3.amazonaws.com/labaye/data/Bay%20Settle ment%20Map%20WI%20Historical%20Bulletin%201926.pdf (accessed on 24 Oct 2016).

[18] 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).

[19] 1845 Chart of Green Bay. Available http://s3.amazonaws.com/labaye/data/1845%20Chart%20of%20Green%20Bay.pdf (accessed on 24 Oct 2016).

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

[21] UW-Green Bay personal communication with Thomas Erdman.

[22] 1845 Map of western lower Green Bay. Available: http://browncounty.maps.arcgis.com/apps/StorytellingSwipe/index.html?appid=72615351ef33434e9a6a1bb5fffdbe9c&webmap=02074b6abfc44b88bfe9e96afe90a014 (accessed on 28 Oct 2016).

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

[24] 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).

[25] 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).

[26] Wisconsin Public Land Survey System (1834) from file "PLSS_SurveyData.shp"

[27] The vegetation pattern around Green Bay in the 1840s as related to geology, soils, and land use by Indians with a detailed look at the Townships of Scott, Green Bay, and Suamico by John Dorney, 1975.

[28] Howlett, Jr. 1974: The rooted vegetation of west Green Bay with reference to environmental change

[29] Harris and Cook 1973: Preimpoundment baseline studies of the Peters Marsh Wildlife Area.

	Black Tern (nested on muskrat houses through the 1980s[30]), Yellow-headed Blackbird, Mallard (*Anas platyrhynchos*), Northern Pintail (*Anas acuta*), Gadwall (*Anas strepera*), teal, American Coot, Common Gallinule, Least Bittern, Sora, King Rail (*Rallus elegans*), Virginia Rail (*Rallus limicola*), Wilson's Snipe (*Gallinago delicata*), Common Tern, Forster's Tern, Marsh Wren, and many others[29]. The marsh also served as a migratory stopover site for waterfowl, waterbirds, landbirds, songbirds, and shorebirds[29]. Despite providing important bird habitat, many outbreaks of botulism occurred in Peters Marsh and other neighboring west shore marshes, thus negatively affecting many waterbirds[31]. Unfortunately, by the late 1990s and early 2000s, lake levels dropped around the same time that *Phragmites* arrived in lower Green Bay. Like most of Green Bay's marshes and other habitats, Peters Marsh soon became invaded by *Phragmites*, which in turn outcompeted the native sedges and grasses that once dominated this marsh. The hybrid cattail also took over the wetter parts of the marsh, which also outcompeted native plants. Thus, today, Peters Marsh is a rather large monoculture of hybrid cattail and *Phragmites* with reed canary grass in the northern section of the marsh where it is drier, though some natives still persist. In 2011-2012, the WDNR applied herbicide primarily targeting *Phragmites* throughout the emergent high energy marsh.[32] Then, in 2015, the Bay-Lake Regional Planning Commission did some follow up herbicide application in Peters Marsh along the southwestern edge of the emergent high energy marsh close to shrub carr.[33] Despite these invasive treatments, the monoculture of hybrid cattail is still prominent today, though there are some native emergent and submergent plants along the southern end of the marsh. Recent efforts have been made to try to re-establish wild celery and wild rice. In June 2015, under the guidance of UW-Green Bay's Dr. Mathew Dornbush, graduate student Brianna Kupsky investigated establishing wild rice, wild celery, and hard-stem bulrush (*Schoenoplectus acutus*) at multiple locations in the southern portion of Peters Marsh[5]. The success of these plantings was mixed. Hard-stem bulrush plantings did not do well, largely due water depth and possibly herbivory. Wild rice overall did not do very well though Kupsky suspects that it might thrive in more open water along the southern edge of the marsh. Lastly, wild celery was the most tolerant of the three species and survived the best. As a follow-up study, Dr. Amy Carrozzino-Lyon, Dr. Patrick Robinson, and others are leading an effort to reintroduce wild rice along the west shore from the Duck Creek area up to Seagull Bar in Marinette, WI, including Peters Marsh. They seeded rice this fall (2017). More results to come. For the past two years, the WDNR has constructed and placed artificial nesting platforms in Peters Marsh to try and encourage Black Terns to nest there[34]. While Black Terns have been found in the LGB&FR AOC during the breeding season, they have not used these nesting platforms, and no one has confirmed breeding for this species yet in the lower bay[10].

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[30] AOC Stakeholder's Meeting on 23 June 2015; noted by Dr. H.J. "Bud" Harris

[31] Roznik 1979 Concept Element of the Green Bay West Shore Wildlife Area Master Plan

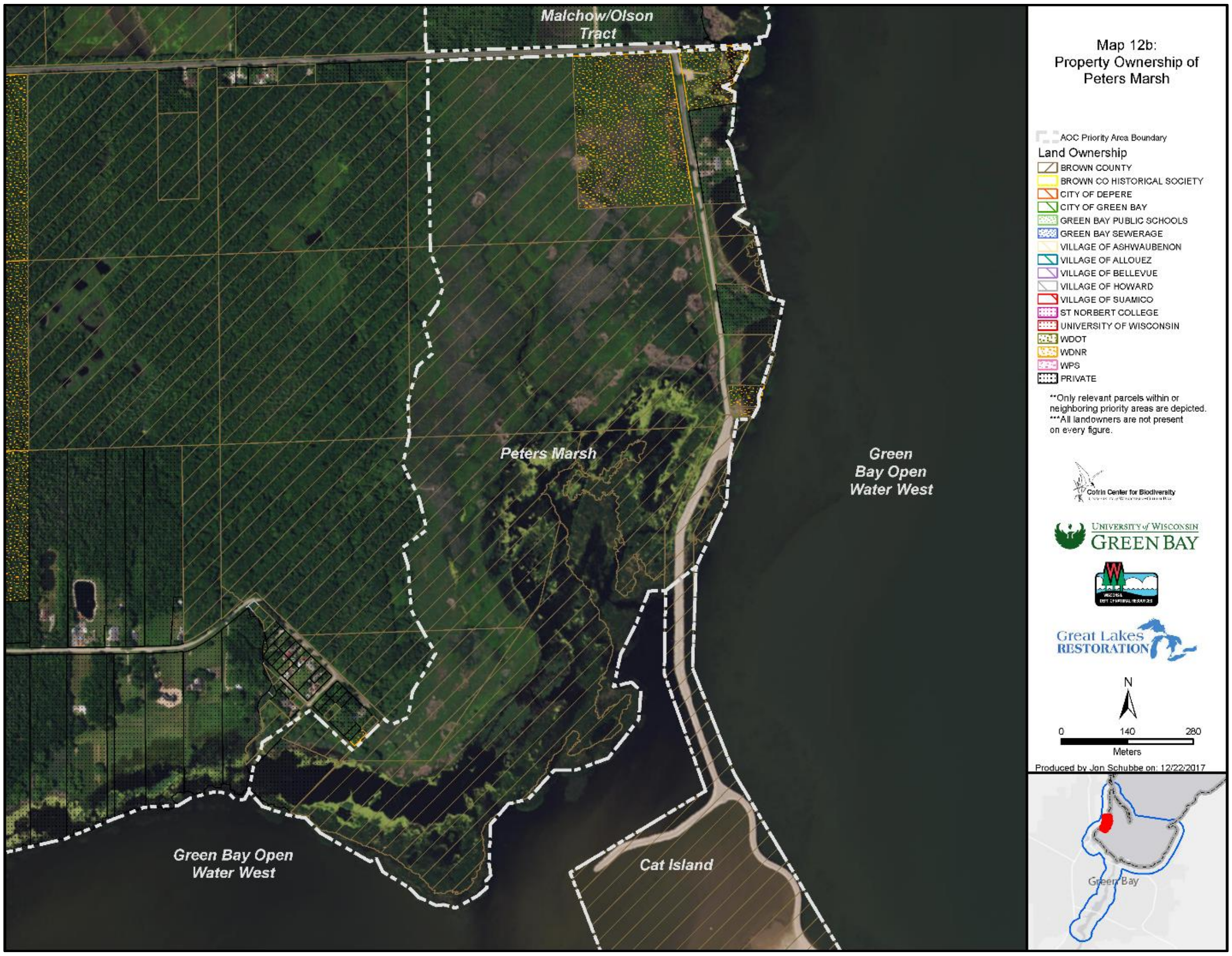
[32] WDNR Phragmites treatment shapefile: "Aerial.shp"

[33] Bay-Lake Regional Planning Commission Phragmites treatment shapefile: "GLFWRA_Phrag2015_16_aoc.shp"

[34] Personal communication with Joshua Martinez

Map of Peters Marsh 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.

Land ownership boundaries at Peters Marsh. Map made by UW-Green Bay’s Jon Schubbe.



Photograph of Peters Marsh facing west. Photograph taken by Erin Giese on 2 December 2016.

Appendix 10.11: Point Sable

Written by Erin Giese, James Horn, and Bobbie Webster

<table>
<tr><td>Location (centroid)</td><td>Lat. 44.579726°, Lon. -87.901034°[1] (NAD 1983, UTM Zone 16N)</td></tr>
<tr><td>Total Area (ha)</td><td>118.47 ha</td></tr>
<tr><td>Area Public Land (ha)</td><td>77.2 ha</td></tr>
<tr><td>Area of Habitat Types Present (ha) and Percent of Each Habitat Type</td><td>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&FR AOC)[2]. Habitat types within Point Sable 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 116.84 ha of natural habitat within Point Sable.
<table>
<tr><th>Habitat Type</th><th>Area (ha)</th><th>Percent</th></tr>
<tr><td>Emergent Marsh (High Energy Coastal)</td><td>1.61</td><td>1.37</td></tr>
<tr><td>Emergent Marsh (Inland)</td><td>39.63</td><td>33.92</td></tr>
<tr><td>Great Lakes Beach</td><td>5.91</td><td>5.06</td></tr>
<tr><td>Hardwood Swamp</td><td>45.21</td><td>38.69</td></tr>
<tr><td>Northern Mesic Forest</td><td>0.66</td><td>0.57</td></tr>
<tr><td>Open Water Inland</td><td>0.06</td><td>0.05</td></tr>
<tr><td>Other Forest</td><td>11.53</td><td>9.87</td></tr>
<tr><td>Southern Sedge Meadow</td><td>0.10</td><td>0.08</td></tr>
<tr><td>Submergent Marsh</td><td>9.48</td><td>8.11</td></tr>
<tr><td>Surrogate Grassland (Old Field)</td><td>2.46</td><td>2.11</td></tr>
<tr><td>Tributary Open Water</td><td>0.19</td><td>0.16</td></tr>
</table>
<i>Disclaimer! 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, late summer/fall 2016 and 2017. Great Lakes water levels were much higher in 2016 and 2017 than in July 2015.</i></td></tr>
<tr><td>General Description</td><td>Point au Sable is a peninsula located along the eastern shore of the bay of Green Bay, approximately 10 km northeast of the city of Green Bay (in the town of Scott), and constitutes the LGB&FR AOC northeastern-most boundary. It consists of a wide variety of habitats including emergent marsh, hardwood swamp, Great Lakes beach, and a small patch of southern sedge meadow[2]. In fact, the Point contains one of the largest remaining Great Lakes coastal wetlands along the bay of Green Bay's eastern shore[4]. It primarily consists of Tedrow loamy fine sand, ruse silt loam, and Markey</td></tr>
</table>

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[1] File "AOC_PriorityAreas.v09_20171212.shp"

[2] LGB&FR AOC 2015 habitat field mapping effort

	muck soils[3]. Today, Pt. au Sable is primarily owned and managed by the Cofrin Center for Biodiversity (CCB) at the University of Wisconsin-Green Bay though some of it is privately owned; the university portion is officially called the "Point au Sable Nature Preserve." Even though several aggressively invasive plant species are frequent to dominant in parts of the Point, it still supports over 200 bird species annually and is an extremely important migratory bird stopover location[4,5] for many waterfowl, Neotropical migrant songbirds, and shorebirds. It is also an important nursery for yellow perch (*Perca flavescens*)[6], provides spawning habitat for northern pike (*Esox lucius*)[6], and is home to over 40 species of fish in Wequiock Creek and offshore areas. Because UW-Green Bay owns most of the Point, it is extremely well-studied by university and agency scientists. CCB staff have been heavily treating and managing invasive plant species, especially the common reed (*Phragmites australis*; hereafter referred to as "*Phragmites*") and understory woody plants (e.g., showy bush honeysuckle [*Lonicera* × *bella*]).
Special Features	• One of the largest remaining Great Lakes coastal wetlands along the eastern shore of lower Green Bay[4], which makes Pt. au Sable extremely dynamic due to changing water levels and seiche; located on a peninsula that extends into lower Green Bay. • Significant migratory bird stopover site, particularly for waterfowl, songbirds, and waterbirds[4,5]. • Nursery for yellow perch and others as well as spawning habitat for predatory fish, including northern pike, bowfin (*Amia calva*), and shortnose gar (*Lepisosteus platostomus*)[6,17]. • Contains habitats rare to both the state of WI and the LGB&FR AOC, namely Great Lakes beach and a small patch of southern sedge meadow[2]. • Contains one of the highest quality hardwood swamps in the LGB&FR AOC (located south of Point Lane; canopy dominated by green ash [*Fraxinus pennsylvanica*] and swamp white oak [*Quercus bicolor*]) because there is a very low abundance of invasive species and a high diversity of native plant species (high native graminoid diversity [50+ species]), including at least three considered to be relatively uncommon or rare in WI and >90 bryophyte species. There are also over a dozen small creeks that traverse through this hardwood swamp. • Contains two of the highest-quality submergent marsh communities in the LGB&FR AOC. • Provides breeding bird habitat for Bald Eagles (*Haliaeetus leucocephalus*), woodpeckers, marsh-nesting birds, and many Neotropical migrant songbirds (e.g., warblers, flycatchers). • Important habitat for muskrats in open water lagoon/emergent marsh. • Breeding habitat for many anuran species.
Natural Habitat Communities and Significant Plants (ordered in terms of ecological importance and size/amount)	Over half of Pt. au Sable consists of **emergent marsh**; the western half of the Point within the open water lagoon is inland emergent marsh while the vegetation alongside Wequiock Creek and in the center of Pt. au Sable makes up a riparian emergent marsh. In both areas, the marshes are largely dominated by *Phragmites* and hybrid cattail (*Typha* × *glauca*) though there are a few native species[2]: • Sedges (*Carex* spp.), occasional • Jewelweed (*Impatiens capensis*), rare • Giant bur-reed (*Sparganium eurycarpum*), rare

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[3] Soil Survey Geographic (SSURGO) by the United States Department of Agriculture's Natural Resources Conservation Service. Published Dec 2010. Available: http://uwgb.maps.arcgis.com/home/item.html?id=204d94c9b1374de9a21574c9efa31164; accessed 14 October 2016.
[4] Epstein et al. 2002
[5] eBird 2016: http://ebird.org/ebird/hotspot/L159724
[6] David Lawrence Cofrin Student Research Grant and UW-Green Bay Senior Thesis 2010-12; Lawrence's sampling took place at Wequiock Creek.

- Soft-stem bulrush (*Schoenoplectus tabernaemontani*), rare
- Broadleaf arrowhead (*Sagittaria latifolia*), rare
- Broadleaf cattail (*Typha latifolia*), rare

The second most common habitat at the Point is **hardwood swamp**[2,7]. One of the highest quality hardwood swamps in the entire LGB&FR AOC, in terms of native plant diversity, is located to the south of Point Lane on the north side of the peninsula[2,7]. Swamp white oak and green ash dominate the tree canopy. The extremely diverse herbaceous layer, with over 40 species of graminoids, includes[7]:

- Fowl manna grass (*Glyceria striata*), common
- Crested sedge (*Carex cristatella*), common
- Woolly sedge (*Carex pellita*), moderately common
- Common lake sedge (*Carex lacustris*), moderately common
- Blue flag iris (*Iris versicolor* & *I. virginica* var. *shrevei*), moderately common
- Small forget-me-not (*Myosotis laxa*), a state special concern species, rare
- Awnless wild-rye (*Elymus curvatus*), rare
- Crested wood fern (*Dryopteris cristata*), rare
- Spinulose wood fern (*Dryopteris carthusiana*), rare
- Great blue lobelia (*Lobelia siphilitica*), rare
- Common hop sedge (*Carex lupulina*), rare
- Common beggar-ticks (*Bidens frondosa*), rare
- Blunt-leaf bedstraw (*Galium obtusum*), rare
- Common water-hemlock (*Cicuta maculata*), rare

Shrubs and woody vines are infrequent here, but when present include red-osier dogwood (*Cornus sericea*), nannyberry (*Viburnum lentago*), thicket creeper (*Parthenocissus inserta*), riverbank grape (*Vitis riparia*), and blackberry/raspberry (*Rubus* spp.)[2].

The remaining hardwood swamp at the Point also contains swamp white oak and green ash but also cottonwood (*Populus deltoides*), box elder (*Acer negundo*), and American elm (*Ulmus americana*). In the understory, which differs from the above in having a much denser shrub layer, there is black cherry (*Prunus serotina*), thicket creeper (*Parthenocissus inserta*), riverbank grape (*Vitis riparia*), gooseberry/currant (*Ribes* spp.), and blackberry/raspberry (*Rubus* spp.)[2].

Great Lakes beach habitat encircles most of the Point and primarily consists of zebra and quagga mussel shells with some sand and matted dead *Phragmites* stems[2]. However, there are a number of important native plants that inhabit these shorelines[7]:

- Cocklebur (*Xanthium strumarium*), common
- American red raspberry (*Rubus idaeus* subsp. *strigosus*), common
- Beach rocket (*Cakile edentula* ssp. *edentula* var. *lacustris*), a state special concern species, moderately common
- Late goldenrod (*Solidago gigantea*), moderately common
- Seaside spurge (*Euphorbia polygonifolia*), a state special concern species, rare
- Sandbar willow (*Salix interior*), rare
- Field horsetail (*Equisetum arvense*), rare
- Threepetal bedstraw (*Galium trifidum*), rare
- Smartweed (*Persicaria* spp.), rare
- Canada wild-rye (*Elymus canadensis*), rare
- Eastern red cedar (*Juniperus virginiana*), rare
- Canadian horseweed (*Conyza canadensis*), rare

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[7] LGB&FR AOC 2016 botanical surveys

One small patch of **southern sedge meadow** still remains and is present east of the central part of the Point, close to Wequiock Creek[2]. Historically, sedge meadows covered a much larger area of the Point. Common tussock sedge (*Carex stricta*) and grasses (Poaceae spp., especially *Calamagrostis canadensis*) are dominants in the meadow, but additionally present are swamp milkweed (*Asclepias incarnata*), spotted joe-pye-weed (*Eutrochium maculatum*), blue vervain (*Verbena hastata*), hedge-nettle (*Stachys palustris*), and sweet-flag (*Acorus americanus*), among others[2].

Southwest of the end of Point Lane, there is a small patch of **northern mesic forest** along the higher, drier stretch of forest that parallels the shoreline. Overall, this habitat is relatively uncommon throughout the LGB&FR AOC. It is dominated by[2]:

- Sugar maple (*Acer saccharum*)
- Basswood (*Tilia americana*)
- Green ash (*Fraxinus pennsylvanica*)
- Box elder *(Acer negundo*)
- Riverbank grape (*Vitis riparia*)
- Zig-zag goldenrod (*Solidago flexicaulis*)

Pt. au Sable contains two, distinct **submergent marsh**[2] communities, each among the most plant species-rich in LGB&FR AOC. The first is the **lagoon**, located within the center of the peninsula. The second is **Wequiock Creek** and its sloughs in the southeastern part of the Point Sable priority area. These two communities have somewhat contrasting species composition, likely because they are each part of different hydrologic systems.

The **lagoon** is without any invasive aquatic macrophytes and contains 17 native species, including:

- Coontail (*Ceratophyllum demersum*), common
- Common bladderwort (*Utricularia vulgaris*), common
- Small duckweed (*Lemna minor*), common
- Flatstem pondweed (*Potamogeton zosteriformis*), moderately common
- Common water-meal (*Wolffia columbiana*), moderately common
- Forked duckweed (*Lemna trisulca*), moderately common
- Slender riccia (*Riccia fluitans*, a thallose liverwort), rare
- Hook moss (*Drepanocladus* sp., a pleurocarpous moss), rare

Wequiock Creek contains the invasive Eurasian water-milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*), which are locally common in the sloughs of the creek. The flora otherwise contains 14 native species, including:

- Common waterweed (*Elodea canadensis*), frequently common
- Turion duckweed (*Lemna turionifera*), common throughout
- Coontail (*Ceratophyllum demersum*), moderately common throughout
- Sago pondweed (*Stuckenia pectinata*), occasionally moderately common
- Thread-leaved pondweed (*Stuckenia filiformis*), rare, but throughout
- Slender waterweed (*Elodea nuttallii*) mostly rare, locally common
- Bull-head pond-lily (*Nuphar variegata*), locally common
- Long-leaved pondweed (*Potamogeton nodosus*), rare, but throughout

On the very southern edge of Pt. au Sable is a large stand of **other forest** consisting of younger trees and shrubs, including[2]:

- Green ash (*Fraxinus pennsylvanica*)
- Cottonwood (*Populus deltoides*)
- Trembling aspen (*Populus tremuloides*)
- White cedar (*Thuja occidentalis*)
- Eastern red-cedar (*Juniperus virginiana*)
- Gray dogwood (*Cornus foemina*)

Significant Animals	**Birds**: • >200 bird species have been recorded across all seasons, including[8]: o Two federal special concern species (Common Tern [*Sterna hirundo*], Golden-winged Warbler [*Vermivora chrysoptera*]) o Five state endangered species (Caspian Tern [*Hydroprogne caspia*], Forster's Tern [*Sterna forsteri*], Common Tern, Peregrine Falcon [*Falco peregrinus*], and Red-necked Grebe [*Podiceps grisegena*]) o One state threatened species (Great Egret [*Ardea alba*]) o Thirty-five Wisconsin Wildlife Action Plan Species of Greatest Concern (e.g., waterfowl, raptors, grebes, songbirds) o Forty-four state special concern species (e.g., American Bittern [*Botaurus lentiginosus*], Canada Warbler [*Cardellina canadensis*], Red-headed Woodpecker [*Melanerpes erythrocephalus*], Swainson's Thrush [*Catharus ustulatus*]) o Eight International Union for Conservation of Nature-listed species as near threatened (e.g., Chimney Swift [*Chaetura pelagica*], Red-headed Woodpecker [*Melanerpes erythrocephalus*]) or vulnerable (e.g., Rusty Blackbird [*Euphagus carolinus*], large flocks stage at Pt. au Sable during migration) o Large numbers of migratory diving ducks (e.g., goldeneye, scaup, mergansers, Ruddy Ducks [*Oxyura jamaicensis*][9]), dabbling ducks (e.g., Mallards [*Anas platyrhynchos*], teal [other *Anas* spp.], Gadwall [*Anas strepera*]), and gulls (e.g., Bonaparte's Gull [*Chroicocephalus philadelphia*]) use the open water lagoon and offshore areas near Pt. au Sable[5,9] o Large numbers of Ruby-crowned Kinglets (*Regulus calendula*), Golden-crowed Kinglets (*Regulus satrapa*), Tennessee Warblers (*Oreothlypis peregrina*), Blackpoll Warblers (*Setophaga striata*), Yellow-rumped Warblers (*Setophaga coronata*), and White-throated Sparrows (*Zonotrichia albicollis*), migrate through lower Green Bay and use Pt. au Sable for stopover habitat[10] • At least 40 bird species are known (or very likely) to breed at Pt. au Sable[11]: o Waterfowl (e.g., Wood Duck [*Aix sponsa*], Canada Goose [*Branta canadensis*]), Bald Eagles, woodpeckers (e.g., Red-headed Woodpecker), flycatchers (e.g., Eastern Kingbird [*Tyrannus tyrannus*], Great Crested Flycatcher [*Myiarchus crinitus*]), warblers (e.g., Common Yellowthroat [*Geothlypis trichas*]), marsh-nesting birds (e.g., Red-winged Blackbird [*Agelaius phoeniceus*]), and others (e.g., Green Heron [*Butorides virescens*], Tree Swallow [*Tachycineta bicolor*], Rose-breasted Grosbeak [*Pheucticus ludovicianus*]). • Not surprisingly, Pt. au Sable is officially a "Migratory Bird Concentration Site" according to the Wisconsin Department of Natural Resources[12]. **Fish**: • >40 species of fish have been detected within Pt. au Sable's waters, such as Wequiock Creek or offshore[6,8,13,14] including: o Yellow perch use Wequiock Creek for nursery habitat and are extremely common[6,13]. Bowfin and shortnose gar also use it for nursery habitat[13] o Gizzard shad (*Dorosoma cepedianum*)[14] o White sucker (*Catostomus commersonii*), relatively common[6,13]

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[8] LGB&FR AOC comprehensive biota database: file "AOCBiota_DB_ShareableVersion_20171210.accdb"

[9] LGB&FR AOC 2016 migratory waterfowl surveys

[10] Stephanie Beilke's UW-Green Bay master's thesis 2014.

[11] Wisconsin Breeding Bird Atlas II Project (2015-2019): http://ebird.org/ebird/atlaswi/block/4408758CE?atlasPeriod=EBIRD_ATL_WI_2015 &rank=mrec&hs_sortBy=category&hs_o=desc (as of 11 Oct 2016).

[12] Wisconsin Department of Natural Resources. 2009. Wisconsin Natural Heritage Working List. http://dnr.wi.gov/topic/NHI/WList.html. (Accessed: 1 Nov 2014).

[13] Fish survey data collected at Pt. au Sable in 2016 led by Collin Moratz.

  - Bluegill sunfish (*Lepomis macrochirus*), relatively common[6]
  - Green sunfish (*Lepomis cyanellus*), relatively common[6]
  - Freshwater drum (*Aplodinotus grunniens*), relatively common[13]
  - Emerald shiner (*Notropis atherinoides*), somewhat common[6,13]
  - Black bullhead (*Ameiurus melas*), common to uncommon[13]
  - Central mudminnow (*Umbra limi*), somewhat common to common[13]
  - Banded killifish (*Fundulus diaphanous*), a state special concern species, Wisconsin Wildlife Action Plan Species of Greatest Concern, and somewhat uncommon[6]
  - Northern pike are known to spawn here though uncommon[6,13]
  - Walleye (*Sander vitreus*), uncommon[6]
  - Largemouth bass (*Micropterus salmoides*)[6,14]
  - Smallmouth bass (*Micropterus dolomieu*)[14]

Mammals:

- 25 mammal species have been documented at Pt. au Sable[8]:
  - Fur bearers: American mink (*Neovison vison*), muskrat (*Ondatra zibethicus*)[15], North American river otter (*Lontra canadensis*), and red fox (*Vulpes vulpes*)
    - At least 15 muskrat (*Ondatra zibethicus*) lodges were found in the lagoon area of Pt. au Sable in 2015[16]
  - Seven bat species were found during migration, including four state threatened species (big brown bag [*Eptesicus fuscus*], little brown bat [*Myotis lucifugus*]; also globally vulnerable], northern long-eared bat [*Myotis septentrionalis*], and tricolored bat [*Perimyotis subflavus*])
  - Rodents: white-footed mouse (*Peromyscus leucopus*) and meadow jumping mouse (*Zapus hudsonius*)

Amphibians:

- Six anuran (frog/toad) species[8]:
  - American toad (*Bufo americanus*), eastern gray treefrog (*Hyla versicolor*), green frog (*Lithobates clamitans*), northern leopard frog (*Lithobates pipiens*), spring peeper (*Pseudacris crucifer*), and wood frog (*Lithobates sylvaticus*)
  - Northern leopard frog is both a federal and state species of special concern

Mollusks:

- Six native species of mussels: fatmucket (*Lampsilis siliquoidea*), fragile papershell (*Leptodea fragilis*), giant floater (*Pyganodon grandis*), pink heelsplitter (*Potamilus alatus*), three-ridge (*Amblema plicata*), and wabask pigtoe (*Fusconaia flava*)[8]

Reptiles:

- Three turtle species: eastern snapping turtle (*Chelydra serpentina*), painted turtle (*Chrysemys picta*), and eastern spiny softshell turtle (*Apalone spinifera*)[8]
- One snake species: common garter snake (*Thamnophis sirtalis*)[8]

Arthropods:

- Many aquatic invertebrates: water beetles (e.g., *Laccophilus* sp.), midges (e.g., *Chironomidae* family), water boatmen (e.g., *Corixidae* family), biting midges (e.g., *Probezzia* sp.), and dragonflies (e.g., black saddlebags [*Tramea lacerate*])[8]
- Over 90 spider species have been recorded[8]

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[14] Wisconsin Department of Natural Resources Fish Trawling Survey Data 1980-2015; sampling points located offshore to south of the Point.

[15] Wisconsin Department of Natural Resources 2015 muskrat house survey; noted in AOC Conservation Project Catalogue.

[16] UW-Green Bay personal communication with Dr. Bob Howe and Michael Stiefvater.

Habitat Quality	The overall ecological quality of Pt. au Sable depends on the habitat type. While there are a few relatively high quality areas in portions of its hardwood swamps, southern sedge meadow, Great Lakes beaches, and submergent marshes, the Point's emergent marsh and parts of its hardwood swamp are in relatively poor ecological condition. The emergent marshes are partially invaded by *Phragmites*, hybrid cattail, and reed canary grass. Few native plants occur in these marshes, though the Cofrin Center for Biodiversity is actively working to control *Phragmites*. Much of the forests are invaded by several woody understory shrubs, garlic mustard (*Alliaria petiolata*), and dame's rocket (*Hesperis matronalis*). That being said, there are small pockets of high quality areas within four habitats: 1. Hardwood Swamp a. Located just south of Point Lane. b. Contains an extremely high native graminoid diversity (50+ species). 2. Southern Sedge Meadow a. Southern sedge meadow is a rare habitat both in the LGB&FR AOC and across the state making this meadow extremely important ecologically-speaking. It is dominated by tussock sedge and grasses. 3. Great Lakes Beach a. Most of the perimeter of the Point contains Great Lakes beach that largely consists of crushed quagga and zebra shells with sand. Great Lakes beach is a relatively rare habitat in the LGB&FR AOC and statewide, and Pt. au Sable's beach consists of some high quality, native plants like beach rocket. 4. Submergent Marsh a. Two, distinctive submergent marsh communities exist at the Point: 1) the lagoon and 2) the Wequiock Creek complex. Both are among the most native plant species-rich submergent marsh communities in the LGB&FR AOC, and they have somewhat contrasting species composition.
Significant Invasive Species Issues	**Invasive Plant Species**[2]: Each of these species outcompetes and crowds out native plants: • Common reed (*Phragmites australis*) o Common and continuing problem; occurs along shoreline, open water lagoon, and emergent marsh; currently being managed. • European buckthorn (*Rhamnus cathartica*) o Common and continuing problem; found in understory of hardwood swamp and northern mesic forest; currently being managed. • Glossy buckthorn (*Frangula alnus*) o Common and continuing problem; found in understory of hardwood swamp and northern mesic forest; currently being managed. • Hybrid cattail (*Typha × glauca*) o Common and continuing problem; occurs in open water lagoon, emergent marsh, and occasionally in understory of hardwood swamp; currently being managed in sedge meadow and in patches in estuary. • Garlic mustard (*Alliaria petiolata*) o Common and continuing problem; found in understory of hardwood swamp and northern mesic forest; currently being managed. • Eurasian water-milfoil (*Myriophyllum spicatum*) o Locally common and sometimes relatively dense upstream in Wequiock Creek; likely negatively affecting fish habitat; not currently being managed[17]. • Curly-leaf pondweed (*Potamogeton crispus*)

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[17] Point au Sable Phase II Fish Restoration Project 2016.

  - Locally common and sometimes relatively dense upstream in Wequiock Creek; likely negatively affecting fish habitat; not currently being managed[18].
- Showy bush honeysuckle (*Lonicera* × *bella*)
  - Common and continuing problem; found in understory of hardwood swamp and northern mesic forest; currently being managed.
- Purple loosestrife (*Lythrum salicaria*)
  - Found occasionally in southern sedge meadow and emergent marsh; not currently being managed.
- Reed canary grass (*Phalaris arundinacea*)
  - Primarily occurs in southern sedge meadow, emergent marsh, and hardwood swamp; currently being managed in sedge meadow and in patches in estuary.
- Canada thistle (*Cirsium arvense*)
  - Common and ongoing problem; currently being managed.
- Spear thistle (*Cirsium vulgare*)
  - Especially invasive in the Great Lakes beach community; not currently being managed.
- Siberian elm (*Ulmus pumila*)
  - Especially invasive in the Great Lakes beach community; not currently being managed.
- Couchgrass (*Elymus repens*)
  - Especially invasive in the Great Lakes beach community; not currently being managed.
- Canada bluegrass (*Poa compressa*)
  - Especially invasive in the Great Lakes beach community; not currently being managed.
- Soapwort (*Saponaria officinalis*)
  - Especially invasive in the Great Lakes beach community; not currently being managed.
- Dame's rocket (*Hesperis matronalis*)
  - Somewhat common and ongoing problem; currently being managed.

Exotic Plant Species:

- Crack willow (*Salix* × *fragilis*)
  - Found in the Great Lakes beach community; not currently being managed.
- Bittersweet nightshade (*Solanum dulcamara*)
  - Common; not currently being managed.
- Hedge-parsley (*Torilis japonica*)
  - Found in the hardwood swamp; all individuals were hand pulled in fall 2016.
- Creeping-Charlie (*Glechoma hereracea*)
  - Common, especially in lowland hardwoods near Point Lane homes; not currently being managed.
- Butter-and-eggs (*Linaria vulgaris*)
  - Common; not currently being managed.
- Common mullein (*Verbascum thapsus*)
  - Common; not currently being managed.
- Gold-moss stonecrop (*Sedum acre*)
  - Common; not currently being managed.
- Hoary-alyssum (*Berteroa incana*)
  - Common; not currently being managed.
- Worm-seed mustard (*Erysimum cheiranthoides*)
  - Common; not currently being managed.

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[18] Point au Sable Phase II Fish Restoration Project 2016.

- Russian olive (*Elaeagnus angustifolia*)
    - Less common than buckthorns and honeysuckle; found in upland and lowland hardwoods; currently being managed.
- Common mouse-ear chickweed (*Cerastium fontanum*)
    - Common; not currently being managed.
- White mulberry (*Morus alba*)
    - Common in upland hardwoods; not currently being managed.

Invasive Animal Species[28]:

- *Arthropods*
    - Cobweb weaver (*Enoplognatha ovata*); not currently being managed

- *Birds*
    - European Starling (*Sturnus vulgaris*)
        - Poses some threat to native species, particularly cavity nesters (e.g., Tree Swallow), by outcompeting them and occupying potential nest sites; not currently being managed.
    - Other exotic or invasive bird species occur at Pt. au Sable, notably Brown-headed Cowbird (*Molothrus ater*), House Sparrow (*Passer domesticus*), and Rock Pigeon (*Columba livia*); however, these species generally do not significantly affect native birds at Pt. au Sable because they tend to inhabit human areas (e.g., developed or agricultural areas).

- *Fish*[8]
    - Alewife (*Alosa pseudoharengus*)
        - Poses a threat to native fish species by consuming a lot of zooplankton and disturbing the natural food web; not currently being managed[19].
    - Common carp (*Cyprinus carpio*)
        - Destroy vegetation by uprooting plants and increasing cloudiness of water; not currently being managed[20].
    - Rainbow smelt (*Osmerus mordax*)
        - Negatively affect uncommon to rare native fish species; not currently being managed[21].
    - Round goby (*Neogobius melanostomus*)
        - Prey on small native fish and eggs (e.g., darters) and outcompete similarly sized native fish; not currently being managed[22].
    - White perch (*Morone americana*)
        - Prey on native fish eggs, such as walleye; not currently being managed[23].

- *Freshwater mussels*
    - Quagga mussel (*Dreissena rostriformis*)

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[19] 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.

[20] 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.

[21] Fuller, P., 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.

[22] 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.

[23] 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 1/7 Oct 2016.

	▪ Poses threat to native freshwater mussels; not currently being managed. o Zebra mussel (*Dreissena polymorpha*) ▪ Poses threat to native freshwater mussels; not currently being managed.
Management and Restoration Recommendations	• Continue current invasive plant species management efforts to control invasives noted above (e.g., *Phragmites*, woody understory plants [honeysuckle, buckthorn]). Efforts to control *Phragmites* may include water level manipulation with pump in open water lagoon and removing invasives. • Ensure that native emergent and submergent plants replace their invasive counterparts to provide high quality fish and wildlife habitat. • Enhance Great Lakes beach habitat by removing invasive plant species, which will improve shorebird habitat. o To create potential breeding habitat for the federally endangered Piping Plover (*Charadrius melodus*), provide a few long stretches of Great Lakes beach with sand, cobble, or shells with little to no vegetation. • Expand existing southern sedge meadow by controlling reed canary grass. • Install permanent floating nest platforms for Black Terns (*Chlidonias niger*) in lagoon[24]. • Introduce mayflies (*Hexagenia* sp.) near the lagoon[24]. • Improve substrate for freshwater mussels and crayfish, which help improve water quality and provide food for migratory waterfowl. • Ensure that native woody shrubs (e.g., grape vine, dogwood, blackberry, raspberry) replace woody invasives to provide food to migratory songbirds.
Reference Links and Documents	**Links**: • Background information on Pt. au Sable prepared by the University of Wisconsin-Green Bay's Cofrin Center for Biodiversity webpage: http://www.uwgb.edu/biodiversity/ natural-areas/pt-au-sable/. • Drone footage of Point au Sable taken on 18 July 2015 by Cody Becker: https://www.youtube.com/watch ?v=lJrH8sA39eA. • WDNR's Webpage on Point Sable: http://dnr.wi.gov/topic/wetlands/cw/NLMich/index.asp?mode=detail&RecID=1E8D922A009 • Patterns of bird migration at the Point au Sable Nature Preserve: http://www.wisconsinbirds.org/migratory/docs/PtSableMigrationPatterns2013.pdf • Coastal Wetland Restoration at the Point au Sable Nature Preserve: http://www.sustainourgreatlakes.org/projects/coastal-wetland-restoration-at-the-pt-sable-nature-preserve/ **Reference Documents**: • Epstein, E.J., E. Spencer, and D. Feldkirchner. 2002. A data compilation and assessment of coastal wetlands of Wisconsin's Great Lakes, final report. Natural Heritage Program, Bureau of Endangered Resources, Wisconsin Department of Natural Resources, Madison, WI, USA. PUBL ER-803 2002. o Available: http://dnr.wi.gov/files/pdf/pubs/er/er0803.pdf. • Frieswyk, C.B., C.A. Johnston, and J.B. Zedler. 2007. Identifying and characterizing dominant plants as an indicator of community condition. Journal of Great Lakes Research. 33(3):125-135. o Available: http://glei.nrri.umn.edu/default/documents/frieswyk_jglr_2007.pdf. • Howe, R., A. Wolf, J. Martinez, B. Galbraith, and G. VanVreede. 2013. Pt. au Sable Nature Preserve Coastal Wetland Restoration Plan - Phase 1.

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[24] UW-Green Bay personal communication with Thomas Erdman.

	o Available: http://www.uwgb.edu/biodiversity/files/pdf/Pt%20Sable%20Management%20Plan%20Phase%201%20v20130501.pdf. - Tulbure, M.G., C.A. Johnston, and D.L. Auger. 2007. Rapid invasion of a Great Lakes coastal wetland by non-native *Phragmites australis* and *Typha*. Journal of Great Lakes Research. 33(3):269-279. o Available: http://www.sciencedirect.com/science/article/pii/S0380133007701 569.
Site History (e.g., original vegetation, past conservation projects)	In the early 1630s, Frenchman Jean Nicolet first arrived in lower Green Bay when it was primarily inhabited by Native American tribes[25]. Through the 1700s and 1800s, European fur trade, duck hunting, logging, shipping, and agriculture were important early industries in lower Green Bay[26,27]. Most of Pt. au Sable became privately owned by a small duck hunting club in the 1800s through the 1900s[4,28], which is primarily why is it relatively undeveloped today. This duck hunting club recognized the importance of the Point for migratory waterfowl use[28]. In fact, among many places in lower Green Bay, Pt. au Sable was known (and is still known) as one of the best duck hunting areas in northeastern region of Wisconsin[28]. Up until the mid-1800s, Native Americans inhabited this region and were known to have a settlement just south of the Point (<0.5 km)[29]. A large estuarine emergent marsh and open water lagoon dominated most of the peninsula[4]. As noted in the 1834 Wisconsin Public Land Survey System (PLSS) records, Great Lakes beach with fine-grained sand traced most of the perimeter of the peninsula with a small but extremely dynamic and fluctuating stream in the southern central portion of the tip[29]. This small inlet connected the Bay of Green Bay with the inner, open water lagoon. Like most Great Lakes coastal wetlands, Pt. au Sable is regularly affected by fluctuating Great Lakes water levels, which causes changes in water depth and plant communities, especially emergent marshes. In the 1970s, for example, Great Lakes water levels rose, which flooded out Pt. au Sable's emergent marsh and lagoon[30]. Wequiock Creek, a stream that traverses across the Point's hardwood swamps and emergent marshes, empties into the bay from the southern part of the peninsula. Most of the emergent marsh historically consisted of native cattail (*Typha latifolia*), broad-leaved arrowhead (*Sagittaria latifolia*), and soft-stem bulrush (*Schoenoplectus tabernaemontani*)[4,30]. The southern sedge meadow, which is still present today on a small scale, likely consisted of sedges and Canada bluejoint grass (C*alamagrostis canadensis*)[31]. Over time, by the late 1960s, each of the early duck hunting club members sold their shares of the Point to club member John ("Jake") Rose[28]. In 1997 John Rose donated most of his property to The Nature Conservancy (TNC) in order to protect the Point for waterfowl[28]. TNC then gave it to UW-Green Bay through the Cofrin Center for Biodiversity (CCB) who still owns the Point today[28]. In the late 1990s and early 2000s, Great Lakes water levels dropped significantly while simultaneously, zebra and quagga mussels piled up along the shore. Both the low water levels and invasive mussels severed the water connection between the small inlet and the bay. Unfortunately, roughly around the same time, *Phragmites* had already colonized along Lake Michigan shorelines and invaded the Point's formerly open water lagoon, emergent marsh, and Great Lakes beach shoreline. The heavily invaded *Phragmites* marsh coupled with low lake levels caused the open water lagoon to dry out almost entirely. Later, in 2011, an adjacent landowner sold other small parcels to the

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[25] Jean Nicolet: French Explorer. By The Editors of Encyclopaedia Britannica. Available: https://www.britannica.com/biography/Jean-Nicolet (accessed on 24 Oct 2016).
[26] City of Green Bay's History Webpage: http://www.ci.green-bay.wi.us/history/1800s.html (accessed on 20 Oct 2016).
[27] 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).
[28] Point au Sable Cofrin Center for Biodiversity Blog: http://www.uwgb.edu/biodiversity/natural-areas/pt-au-sable/
[29] Wisconsin Public Land Survey System (1834) from file "PLSS_SurveyData.shp", compiled by UW-Green Bay's Ellie Roark
[30] Tulbure et al. 2007: Rapid Invasion of a Great Lakes Coastal Wetland by Non-native *Phragmites australis* and *Typha*

	University, who currently owns approximately 77 ha (190 ac) at Pt. au Sable. Most of the sandy beaches were replaced by piles of crushed zebra and quagga mussels. Since the early 2000s, CCB staff and students and UW-Green Bay biology classes have actively managed invasive plants at the Point. Invasives present at Pt. au Sable include *Phragmites*, showy bush honeysuckle, European buckthorn, glossy buckthorn, garlic mustard, reed canary grass, and others. Many of these invasive species management efforts have been successful, such as the pulling or cut-stump treatment of woody shrubs, such as honeysuckle and buckthorn. Native cherry trees and dogwood have since flourished on their own and started replacing these invasive shrubs within the past couple of years. CCB staff have continued to manage invasive woody shrubs, planting native shrubs in the areas where invasives once dominated, and establishing monitoring plots so that progress can be monitored over time. The CCB hired contractors to conduct a prescribed burn (May 2012) and an aerial herbicide spraying (September 2012) of the *Phragmites* located in the area formerly known as the lagoon and the estuarine marsh along Wequiock Creek[31]. Contractors were hired to treat *Phragmites* along the shoreline in 2015 and to treat *Phragmites* in the lagoon and estuary in 2015 and 2016. CCB staff and students have actively cut and bundled remaining patches of *Phragmites* in 2015 and 2016 in the lagoon area. These management actions coupled with higher Great Lakes water levels have significantly cut back on the amount of *Phragmites* present in the lagoon and along the shoreline today. The CCB also purchased and installed a pump near the former inlet on the south side of the Point, which allows them to manipulate the lagoon water levels by pumping water from the bay of Green Bay into the lagoon as needed to maintain stands of native emergent plants[31]. Today, a large portion of the original open water lagoon has returned for the first time in 10-15 years, and some native emergent plants have since colonized the area. Remaining patches of *Phragmites* are still actively being treated or managed by CCB staff. Many adjacent private landowners have also been engaged in and supportive of the CCB's restoration and management efforts. Because Pt. au Sable is owned by UW-Green Bay's CCB, many conservation projects, including research, monitoring, and management, have taken place there for over 30 years. Birds, fish, and plants in particular, have been heavily studied by university faculty, staff, and students and agencies (Wisconsin Department of Natural Resources and U.S. Fish and Wildlife Service)[32,33,34]. Others have studied mammals (bats and muskrats), water quality, plants, aquatic invertebrates, spiders, mussels, odonates (dragonflies and damselflies), and anurans (frogs + toads) at the Point[32].

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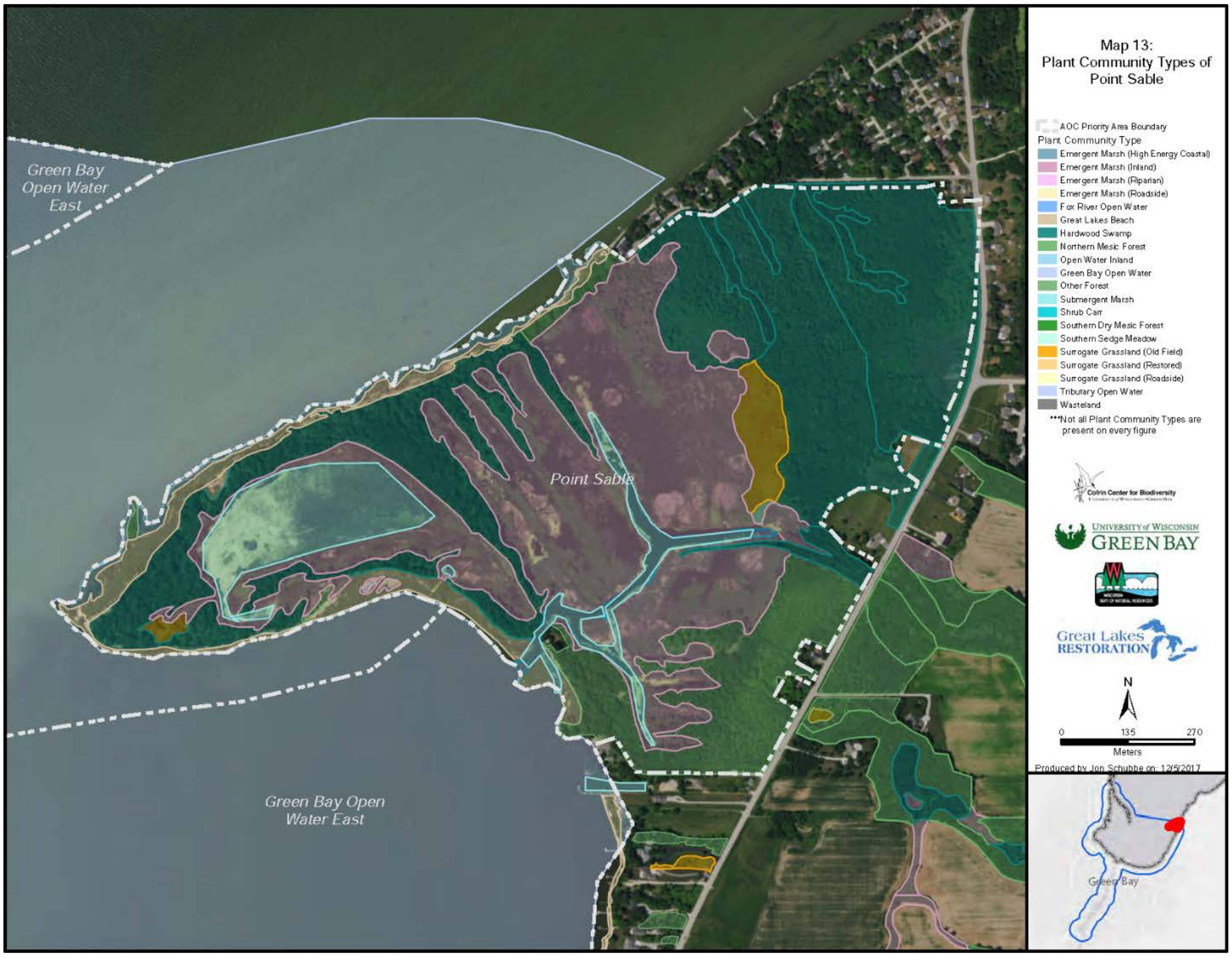
[31] Howe et al. 2013: Pt. au Sable Nature Preserve Coastal Wetland Restoration Plan – Phase 1: http://www.uwgb.edu/biodiversity/files/pdf /Pt%20Sable%20Management%20Plan%20Phase%201%20v20130501.pdf

[32] LGB&FR AOC Comprehensive Conservation Project Catalogue

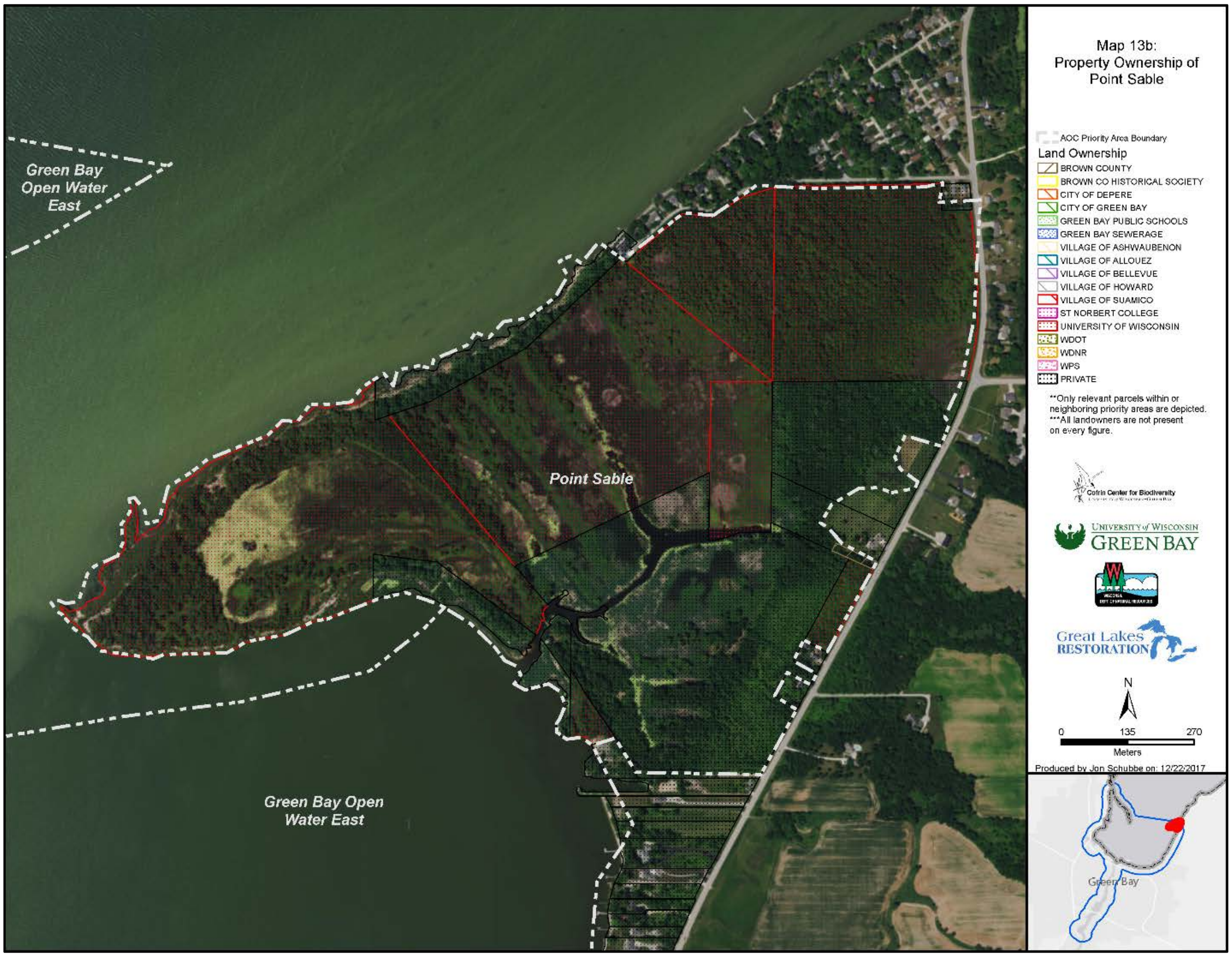
[33] Led by Dr. Patrick Forsythe and Dr. Christopher Houghton: Study on coastal wetland-nearshore linkages of Green Bay sport fishes and habitat food webs. Two of their seven survey locations are in the LGB&FR AOC, namely Dead Horse Bay and Point Sable.

[34] Study on assessment of fish assemblages in lower order tributaries of Green Bay (includes Wequiock Creek); led by Dr. Forsythe and Dr. Houghton

Map of Point Sable’s 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.



Land ownership boundaries at Point Sable. Map made by UW-Green Bay's Jon Schubbe.



Photograph of the Point au Sable peninsula featuring Great Lakes beach habitat along the perimeter, lagoon, emergent marsh, and hardwood swamp (facing east). Photograph taken by Erin Giese on 2 December 2016.

Photograph of the Point Sable peninsula featuring Great Lakes beach habitat along the perimeter, Wequiock Creek, emergent marsh, and hardwood swamp (facing southeast). Photograph taken by Erin Giese on 2 December 2016.

Appendix 10.12: Upper Duck Creek North

Written by Erin Giese and James Horn

<table>
<tr><td>Location (centroid)</td><td>Lat. 44.569848°, Lon. -88.053762°[1] (NAD 1983, UTM Zone 16N)</td></tr>
<tr><td>Total Area (ha)</td><td>85.31 ha</td></tr>
<tr><td>Area Public Land (ha)</td><td>65.77 ha, land owned by the Wisconsin Department of Natural Resources</td></tr>
<tr><td>Area of Habitat Types Present (ha) and Percent of Each Habitat Type</td><td>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&FR AOC)[2]. Habitat types within Upper Duck Creek North 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 84.31 ha of natural habitat in Upper Duck Creek North.
<table>
<tr><th>Habitat Type</th><th>Area (ha)</th><th>Percent</th></tr>
<tr><td>Emergent Marsh (Inland)</td><td>2.05</td><td>2.43</td></tr>
<tr><td>Emergent Marsh (Riparian)</td><td>26.34</td><td>31.24</td></tr>
<tr><td>Emergent Marsh (Roadside)</td><td>1.18</td><td>1.39</td></tr>
<tr><td>Hardwood Swamp</td><td>14.46</td><td>17.15</td></tr>
<tr><td>Open Water Inland</td><td>0.08</td><td>0.10</td></tr>
<tr><td>Other Forest</td><td>26.65</td><td>31.61</td></tr>
<tr><td>Shrub Carr</td><td>8.60</td><td>10.20</td></tr>
<tr><td>Submergent Marsh</td><td>3.04</td><td>3.61</td></tr>
<tr><td>Surrogate Grassland (Old Field)</td><td>1.91</td><td>2.26</td></tr>
</table>
<i>Disclaimer! 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 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.</i></td></tr>
<tr><td>General Description</td><td>Upper Duck Creek North is located just west of the mouth of Duck Creek and Interstate 41 and is a part of the Duck Creek Delta wetland complex. While the priority area has been significantly modified over the years from development, road construction, and agricultural/storm water runoff, it still features a hydrologic habitat gradient that grades from submergent/emergent marsh into southern sedge meadow, shrub carr, and hardwood swamp[2]. While the emergent marsh is heavily dominated by the invasive, hybrid cattail (<i>Typha</i> × <i>glauca</i>), parts of the shrub carr and especially southern sedge meadow have good quality plants[5], though restoration would significantly improve their overall ecological quality. Duck Creek flows northeast from roughly 22 km (13.8 mi) inland and empties into the bay of Green Bay, though it has been known to reverse course and flow upstream (i.e., southwest) as far as 6.4 km (4 mi) during high water levels and seiche in the bay[9]. It primarily consists of Tedrow loamy fine sand soils and</td></tr>
</table>

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[1] File "AOC_PriorityAreas.v09_20171212.shp"

[2] LGB&FR AOC 2015 habitat field mapping effort

	Keowns silt loam[3]. While many parts of the Duck Creek Delta are heavily studied in the lower bay, the Upper Duck Creek North priority area is not well studied, at least not in recent years, with a few exceptions. By the fall of 2012, the Oneida Tribe removed two dams and modified an existing dam upstream in Pamperin Park, which improved fish habitat for species such as northern pike (*Esox lucius*)[35]. The UW-Green Bay's CCB led a LGB&FR AOC bird survey in 2015, habitat mapping effort in 2015, plant biodiversity hotspot mapping and inventory in 2016, and submerged aquatic vegetation mapping in 2017. All surveys included visits to the Upper Duck Creek North priority area. The WDNR has also conducted an aerial spraying of herbicide to manage common reed (*Phragmites australis*) along the west shore. They sprayed this priority area's emergent marsh in 2012.
Special Features	• Offers a landscape of submergent and emergent marsh that grades into southern sedge meadow, shrub carr, and hardwood swamp; this landscape describes the historical mosaic originally found in lower Green Bay[2,4,5]. • Features a small patch of southern sedge meadow, which is a rare habitat in the LGB&FR AOC and across the state, that is largely dominated by blue-joint grass (*Calamagrostis canadensis*), common tussock sedge (*Carex stricta*), and common lake sedge (*Carex lacustris*). • Important habitat for muskrats[6] and wetland birds (e.g., Swamp Sparrow [*Melospiza georgiana*], Marsh Wren [*Cistothorus palustris*]) in the emergent marsh.
Natural Habitat Communities and Significant Plants (ordered in terms of ecological importance and size/amount)	Despite many anthropogenic modifications, the Duck Creek Estuary North priority area still maintains a natural coastal gradient from submergent marsh, to emergent marsh, southern sedge meadow, shrub carr, and finally to hardwood swamp. Roughly one-third of this priority area consists of **emergent marsh (riparian)**, which is mostly dominated by hybrid cattail (*Typha* × *glauca*) toward the centers of the marsh and common reed (*Phragmites australis*; hereafter referred to as *Phragmites*) along the periphery. Most of the native plants are found along the edges of the marsh with little cover[5]. Natives include[5]: • Canada blue-joint grass (*Calamagrostis canadensis*) • Common tussock sedge (*Carex stricta*) • Common great angelica (*Angelica atropurpurea*) • Water smartweed (*Persicaria amphibia*) • Prairie cord grass (*Spartina pectinata*) • Spotted joe-pye weed (*Eutrochium maculatum*) Like emergent marsh (riparian), **other forest** constitutes roughly one-third of this priority area's habitats and is found in the northern half/northwestern corner[2]. Trembling aspen (*Populus tremuloides*), wild grape (*Vitis riparia*), cottonwood (*Populus deltoides*), and white poplar (*Populus alba*) occur here[2]. Approximately 17% of this priority area is made up of **hardwood swamp**, which is found in the far southwestern corner and northeastern edge[5]. Canopy dominants include green ash (*Fraxinus pennsylvanica*), swamp white oak (*Quercus bicolor*), box elder (*Acer negundo*), and cottonwood[5]. The understory is invaded by common buckthorn (*Rhamnus cathartica*) and glossy buckthorn (*Frangula alnus*) but also has native wild grape[5]. The herbaceous layer consists of small-spike false nettle (*Boehmeria cylindrica*), reed canary grass (*Phalaris arundinacea*), and others[5].

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[3] Soil Survey Geographic (SSURGO) by the United States Department of Agriculture's Natural Resources Conservation Service. Published Dec 2010. Available: http://uwgb.maps.arcgis.com/home/item.html?id=204d94c9b1374de9a21574c9efa31164; accessed 15 Dec 2017

[4] Bertrand et al. 1976: The Green Bay Watershed Past/Present/Future

[5] LGB&FR AOC plant biodiversity hotspots field effort

[6] Muskrat lodges can easily be seen in the emergent marsh when looking at aerial imagery

	A linear stretch of **shrub carr** constitutes close to 10% of natural habitat in this priority area and is dominated by meadow willow (*Salix petiolaris*), sandbar willow (*Salix interior*), diamond willow (*Salix eriocephala*), and glossy buckthorn[2,5]. Just over 3.5% of the natural habitats in this priority area is **submergent marsh**, which occurs throughout the stream inlet that runs straight north from the main stem of Duck Creek[2,37]. Dominants include fragrant water-lily, (*Nymphaea odorata*), coontail (*Ceratophyllum demersum*), sago pondweed (*Stuckenia pectinata*), perennial duckweed (*Lemna turionifera*)[37]. Invasives Eurasian water-milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) occur here as well though they are not the dominants[37]. Along the southern edge of this priority area, submergent marsh dominants include coontail, great duckweed (*Spirodela polyrrhiza*), water stargrass (*Heteranthera dubia*), flat-stem pondweed (*Potamogeton zosteriformis*), and small duckweed (*Lemna minor*)[37]. There is a small patch of **surrogate grassland (old field)** that is 1.91 ha in size in the northeastern corner of the priority area[2]. There is a nice mix of native plants, including native eudicot species, such as Canadian goldenrod (*Solidago canadensis*), bee balm (*Monarda fistulosa*), Culver's-root (*Veronicastrum virginicum*), and common milkweed (*Asclepias syriaca*).[2] Between the hardwood swamp in the southwestern corner and the emergent marsh (riparian) in the center is **emergent marsh (inland)** and makes up <2.5% this priority area. There is also a small patch of relatively good and appreciably native-rich, **southern sedge meadow** that is largely dominated by blue-joint grass (*Calamagrostis canadensis*), common tussock sedge (*Carex stricta*), common lake sedge (*Carex lacustris*). Other natives found moderately often include broad-leaved woolly sedge (*Carex pellita*) and marsh bluegrass (*Poa palustris*). Unusual species include swamp betony (*Pedicularis lanceolata*), common water dropwort (*Oxypolis rigidior*), northern meadow spike-moss (*Selaginella eclipes*), and nodding lady's tresses (*Spiranthes cernua*). Moderately common, though not dominant, invasive species include reed canary grass, redtop (*Agrostis gigantea*), and Canada thistle (*Cirsium arvense*). This sedge meadow was not digitized or mapped during the 2015 LGB&FR AOC field effort because it is very small, which is why it is not shown in the habitat map below. Its general location is identified with a star symbol.
Significant Animals	**Birds**: • Over 200 bird species have been recorded along parts of the west shore, however, there are records of just over 60 species reported within the Duck Creek area west of Interstate 41, including[7] o Two state endangered species (Common Tern [*Sterna hirundo*], Forster's Tern [*Sterna forsteri*]) o One state threatened species: Great Egret (*Ardea alba*) o Five state special concern species: American White Pelican (*Pelecanus erythrorhynchos*), Black-crowned Night-Heron (*Nycticorax nycticorax*), Canvasback (*Aythya valisineria*), Common Goldeneye (*Bucephala clangula*), and Redhead (*Aythya americana*) o Six Wisconsin Wildlife Action Plan Species of Greatest Concern (e.g., Trumpeter Swan [*Cygnus buccinator*], Great Egret, Redhead) o Five state special concern species (e.g., American White Pelican, Common Goldeneye)

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[7] LGB&FR AOC Biota Database: file "AOCBiota_DB_ShareableVersion_20171213.accdb"

	• Despite the emergent marsh's lack of native plant diversity, it provides nesting habitat for many marsh-breeding birds[8]:
	  o Red-winged Blackbird (*Agelaius phoeniceus*)
	  o Swamp Sparrow (*Melospiza georgiana*)
	  o Marsh Wren (*Cistothorus palustris*)
	  o Common Yellowthroat (*Geothlypis trichas*)
	• Cliff Swallows (*Petrochelidon pyrrhonota*) and Barn Swallows (*Hirundo rustica*) nest under the Interstate 41 bridge along the eastern edge of this priority area's border[8].
	
	Fish:
	• Although >80 fish species have been recorded in the pelagic zone of the lower bay, only some may use areas near the Duck Creek Delta. Species that use the bay include[7]:
	  o One federally endangered species: chinook salmon (*Oncorhynchus tshawytscha*)
	  o Three state special concern species, including: American eel (*Anguilla rostrata*), banded killifish (*Fundulus diaphanus*), and lake sturgeon (*Acipenser fulvescens*)
	  o One International Union for Conservation of Nature-listed species as "vulnerable" (bloater [*Coregonus hoyi*]) and one as "endangered" (American eel)
	  o Two globally list species (G3 = vulnerable): redside dace (*Clinostomus elongatus*) and lake sturgeon (*Acipenser fulvescens*)
	  o Northern pike (*Esox lucius*)
	
	Mammals:
	• Although ~50 mammal species are known to or are expected to occur along the west shore (as noted in Roznik 1979)[9], only a few likely use the emergent and submergent marshes of Upper Duck Creek North, including muskrat (*Ondatra zibethicus*), North American river otter (*Lontra canadensis*), and American mink (*Neovison vison*)[10,11].
	  o In fact, when looking at Google Earth's 2017 aerial imagery, dozens of muskrat lodges are visible along the southern edge of this priority area in the emergent marsh.
	• Common terrestrial mammals, such as eastern gray squirrel (*Sciurus carolinensis*), eastern chipmunk (*Tamias striatus*), and eastern cottontail (*Sylvilagus floridanus*), likely use the hardwood swamp and other forest habitats[7].
	
	Anurans:
	• Spring peeper (*Pseudacris crucifer*) and American toad (*Bufo americanus*) have been recorded calling within the emergent marsh of neighboring priority area, Duck Creek Estuary North, based on 2012 and 2017 surveys[12]. Other anurans may use this marsh, too, such as eastern gray treefrog (*Hyla versicolor*).

Habitat Quality	Overall, the ecological quality of Upper Duck Creek North's habitats is mediocre though parts of this priority area are in fairly good condition. For example, there is a nice mix of native plants in the submergent marsh and southern sedge meadow, in which invasive plants are not the dominants. There is great potential for this priority area to be improved and restored, particularly the southern sedge meadow, which could be expanded. On the other hand, the emergent marsh (riparian) is heavily invaded by the hybrid cattail and *Phragmites* and thus is currently in poor ecological condition.

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[8] WI Breeding Bird Atlas II Project – data available here: http://ebird.org/ebird/atlaswi/explore

[9] Green Bay West Shores Master Plan Concept Element 1979 by Roznik et al.

[10] Wisconsin Department of Natural Resources Technical Report PUB-LF-073

[11] Wisconsin Department of Natural Resources 2015 muskrat house survey

[12] Great Lakes Coastal Wetland Monitoring Program anuran surveys, 2012 and 2017; per Erin Giese

Significant Invasive Species Issues	**Invasive Plant Species**: Each of these species outcompetes and crowds out native plants[2,5,37]:
	• Eurasian water-milfoil (*Myriophyllum spicatum*)
	  o Found within the submergent marsh mixed in with native submergent species
	• Curly-leaf pondweed (*Potamogeton crispus*)
	  o Found within the submergent marsh mixed in with native submergent species
	• Common reed (*Phragmites australis*)
	  o *Phragmites* is found in the emergent marsh; some management has occurred in open areas of the emergent marsh in 2012 by the WDNR
	• Hybrid cattail (*Typha* × *glauca*)
	  o Largely dominates the emergent marsh
	• Glossy buckthorn (*Frangula alnus*)
	  o Commonly found throughout most of the hardwood swamp
	• Common buckthorn (*Rhamnus cathartica*)
	  o Found in the hardwood swamp
	• Reed canary grass (*Phalaris arundinacea*)
	  o Found in the small patch of southern sedge meadow, though it is not a dominant, and in the hardwood swamp
	• Honeysuckle (*Lonicera* × *bella*)
	  o Found in the hardwood swamp along the southern border of this priority area
	• European fireweed (*Epilobium hirsutum*)
	  o Found in the edges of the emergent marsh vegetation and in ditches along West Deerfield Avenue near Deerfield Docks boat landing
	
	Invasive Animal Species:
	• *Birds*[7]
	  o European Starling (*Sturnus vulgaris*)
	    ▪ Poses some threat to native species, particularly cavity nesters (e.g., Tree Swallow), by outcompeting them and occupying potential nest sites; not currently being managed
	  o It is extremely possible that House Sparrows (*Passer domesticus*) occur along the road/interstate, potentially outcompeting Cliff and Barn Swallows for nests since House Sparrows are known to use old swallow nests; not currently being managed
	
	• *Fish*[7]
	  o Alewife (*Alosa pseudoharengus*)[13]
	    ▪ Poses a threat to native fish species by consuming zooplankton and disturbing the natural food web; not currently being managed
	  o Common carp (*Cyprinus carpio*)[14]
	    ▪ Destroy vegetation by uprooting plants and increasing cloudiness of water; not currently being managed
	  o Rainbow smelt (*Osmerus mordax*)[15]

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[13] 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

[14] 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

[15] 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

	▪ Negatively affect uncommon to rare native fish species; not currently being managed ○ Round goby (*Neogobius melanostomus*)[16] ▪ Prey on small native fish and eggs (e.g., darters) and outcompete similarly sized native fish; not currently being managed ○ White perch (*Morone americana*)[17] ▪ Prey on native fish eggs, such as walleye; not currently being managed • *Freshwater mussels* ○ Zebra mussel (*Dreissena polymorpha*)[18] - it is unknown whether zebra mussels occur at this priority area ▪ Poses threat to native freshwater mussels; not currently being managed.
Management and Restoration Recommendations	• Control the spread of *Phragmites* and invasive cattail and maintain extensive, high quality native plants in the emergent marsh (riparian). • Expand existing southern sedge meadow remnants, control invasive plants, restore hydrology if needed, and promote the spread of native plants. • Control introduced plant species (e.g., Eurasian watermilfoil) and improve the good quality submerged aquatic vegetation with native plants at Duck Creek. • Control woody invasive plants (e.g., glossy buckthorn) in the hardwood swamp. • Place woody debris for fish habitat. • Promote best management practices and innovative nutrient management measures in the Fox River watershed.
Reference Links and Documents	**Web Links**: • Dam removal on Duck Creek with Oneida Tribe, Wisconsin Department of Natural Resources, Brown County, U.S. Fish and Wildlife Service, and Oneida Golf and Country Club: https://greatlakesinform.org/projects-and-progress/498 • History of the Village of Howard as it pertains to the Duck Creek area: http://www.villageofhoward.com/245/History • Nonpoint Source Control Plan for the Duck, Apple, and Ashwaubenon Creeks Priority Watershed Project: http://dnr.wi.gov/topic/nonpoint/documents/9kep/Duck_Apple_Ashwaubenon_Creeks-Plan.pdf **Reference Documents**: • Bosley, T.R. 1978. Loss of wetlands on the west shore of Green Bay. Wisconsin Academy of Sciences, Arts, and Letters 66:235-245. • 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. • Dorney, J.R. 1975 The vegetation pattern around Green Bay in the 1840s as related to geology, soils, and land use by Indians with a detailed look at the Townships of Scott, Green Bay, and Suamico. Book available through the UW-Green Bay Cofrin Library Archives and Area Research Center.

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[16] 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

[17] 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

[18] Wisconsin Department of Natural Resources Technical Report PUBL ER-818 2010

	• Frieswyk, C.B., C.A. Johnston, and J.B. Zedler. 2007. Identifying and characterizing dominant plants as an indicator of community condition. Journal of Great Lakes Research. 33(3):125-135. o Available: http://glei.nrri.umn.edu/default/documents/frieswyk_jglr_2007.pdf • Wisconsin Department of Natural Resources. 2013. Regional and property analysis: Green Bay Planning Group. Technical Report PUB-LF-073. • Wisconsin Department of Natural Resources. 2014. Green Bay Planning Group Master Plan. Technical Report PUB-LF-075.
Site History (e.g., original vegetation, past conservation projects)	In the early 1630s, Frenchman Jean Nicolet first arrived in lower Green Bay when it was primarily inhabited by Native American tribes[19]. Lower Green Bay consisted of large beds of wild rice (*Zizania* sp.) and wild celery (*Vallisneria americana*), extensive emergent marsh (*Schoenoplectus* sp., cattail [*Typha latifolia*]), sedge meadows (*Calamagrostis canadensis*), shrub carr (e.g., *Cornus* spp., *Salix* spp.), swamps, and wet conifer forest (black spruce [*Picea mariana*], balsam fir [*Abies balsamea*])[20,21,22,23,24]. Between the late 1600s and 1800s, European fur trade, duck hunting, fishing, logging, shipping, and agriculture were important early industries in lower Green Bay[25,26,27]. In the early 1800s, there were a few small settlements and farms of Europeans and Native Americans in the lower Bay[26]. In fact, there were a few Native American campsites near the mouth of Duck Creek with villages further upstream[28]. Historical vegetation of the Duck Creek Delta was described as consisting of a grassy marsh and meadow with swamp forest of tamarack and black ash[28,29]. Early European settlers founded the Town of Howard in 1835 and settled along Duck Creek. Residents worked in the timber, farming, quarry, and mail carrier businesses[30]. Most of the present day Upper Duck Creek North priority area was used for farming, which is visible in the 1938 air photo and perhaps maintained as farmland into the 1960s and 1970s, as shown in the Brown County Online GIS Portal. In the late 1960s and early 1970s, vegetation associated with Atkinson's Marsh, which is a part of the Duck Creek Delta complex, consisted of bulrush (*Scirpus* spp.), spike-rush (*Eleocharis* spp.), cattail, sedges (*Carex* spp.), grasses (*Calamagrostis* spp.), and organic mats of vegetation[31]. Panfish, carp, bullhead, yellow perch, and northern pike

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[19] Jean Nicolet: French Explorer. By The Editors of Encyclopaedia Britannica. Available: https://www.britannica.com/biography/Jean-Nicolet (accessed on 24 Oct 2016)

[20] Arthur C. Neville's Map of Historic Sites on Green Bay, Wisconsin 1669-1689. Available: http://s3.amazonaws.com/labaye/data/Bay%20Settle ment%20Map%20WI%20Historical%20Bulletin%201926.pdf (accessed on 24 Oct 2016)

[21] 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)

[22] 1845 Chart of Green Bay. Available http://s3.amazonaws.com/labaye/data/1845%20Chart%20of%20Green%20Bay.pdf (accessed on 24 Oct 2016)

[23] 1820s Fox River Military Road Map to Ft. Crawford. Available: http://s3.amazonaws.com/labaye/data/1820s%20Fox%20River%20Military%20 Road%20Map%20to%20Ft.%20Crawford.pdf (accessed on 24 Oct 2016)

[24] Personal communication with Thomas Erdman

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

[26] 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)

[27] 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)

[28] The vegetation pattern around Green Bay in the 1840s as related to geology, soils, and land use by Indians with a detailed look at the Townships of Scott, Green Bay, and Suamico by John Dorney, 1975

[29] Wisconsin Public Land Survey System (1834) from file "PLSS_SurveyData.shp"

[30] History of the Village of Howard: http://www.villageofhoward.com/245/History (accessed on 16 Dec 2017)

[31] Howlett, Jr. 1974: The rooted vegetation of west Green Bay with reference to environmental change

	were found in large numbers in Duck Creek in the 1970s, especially yellow perch[9,32]. In fact, there used to be a carp fishing crew based out of the Duck Creek area[31]. Unfortunately, between 1834 and 1975, 3.64 km^2 (2.26 mi^2) out of 4.07 km^2 (2.53 mi^2) of marsh were lost between the Fox River and Duck Creek due to the construction of Highways 41 and 141, a landfill, and dredge spoil deposition[33]. Between Duck Creek and the Little Suamico River, 1.92 km^2 (1.19 mi^2) out of 2.56 km^2 (1.59 mi^2) of wetland were also lost[33]. Unlike many parts of the Duck Creek Delta, the Upper Duck Creek North priority area is not well studied, at least not in recent years, with a few exceptions: • In 2012, the WDNR applied herbicide primarily targeting *Phragmites* throughout the emergent high energy marsh in Upper Duck Creek North[34]. • The Oneida Tribe recently led a dam removal project in collaboration with the WDNR, Brown County, FWS, and the Oneida Golf and Country Club[35]. By the fall of 2012, they had removed two dams and modified another one in order to improve fish passage for northern pike and other fish species[35]. • A group of high school students and teachers have conducted water quality monitoring (e.g., stream flow, pH, dissolved oxygen) for many years further upstream in Duck Creek for the Lower Fox River Watershed Monitoring Program[36]. • The UW-Green Bay's Cofrin Center for Biodiversity led a LGB&FR AOC bird survey effort in 2015, habitat mapping effort in 2015, plant biodiversity hotspot mapping and inventory in 2016, and submerged aquatic vegetation mapping in 2017[37]. All of these field efforts included surveys at Upper Duck Creek North.

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[32] Fish and Wildlife Resources of the Great Lakes Coastal Wetlands within the United States, Volume 5: Lake Michigan, Part 3, October 1981

[33] Bosley 1978: Loss of wetlands on the west shore of Green Bay

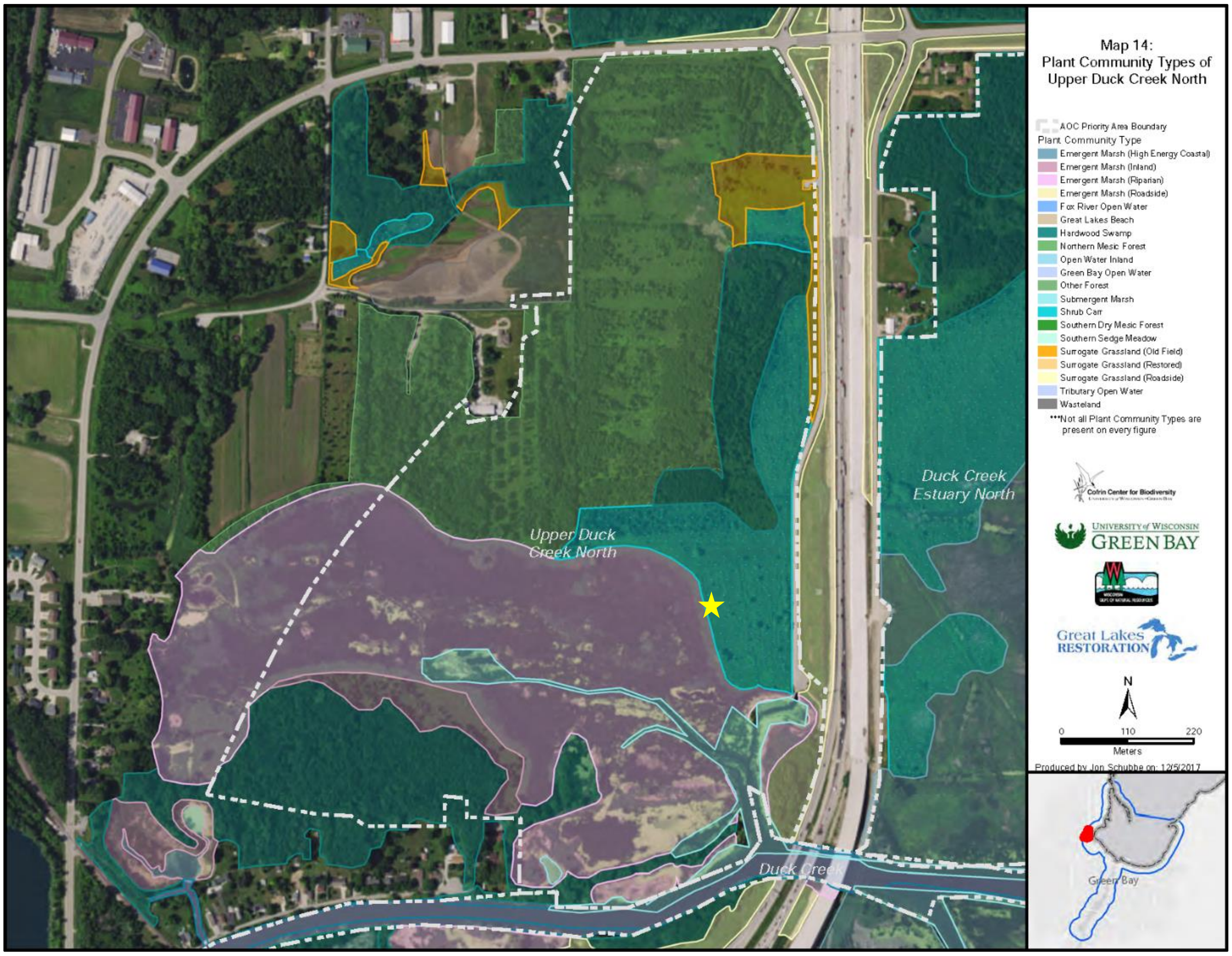
[34] WDNR Phragmites treatment shapefile: "Aerial.shp"

[35] Dam removal project led by the Oneida Tribe: https://greatlakesinform.org/projects-and-progress/498

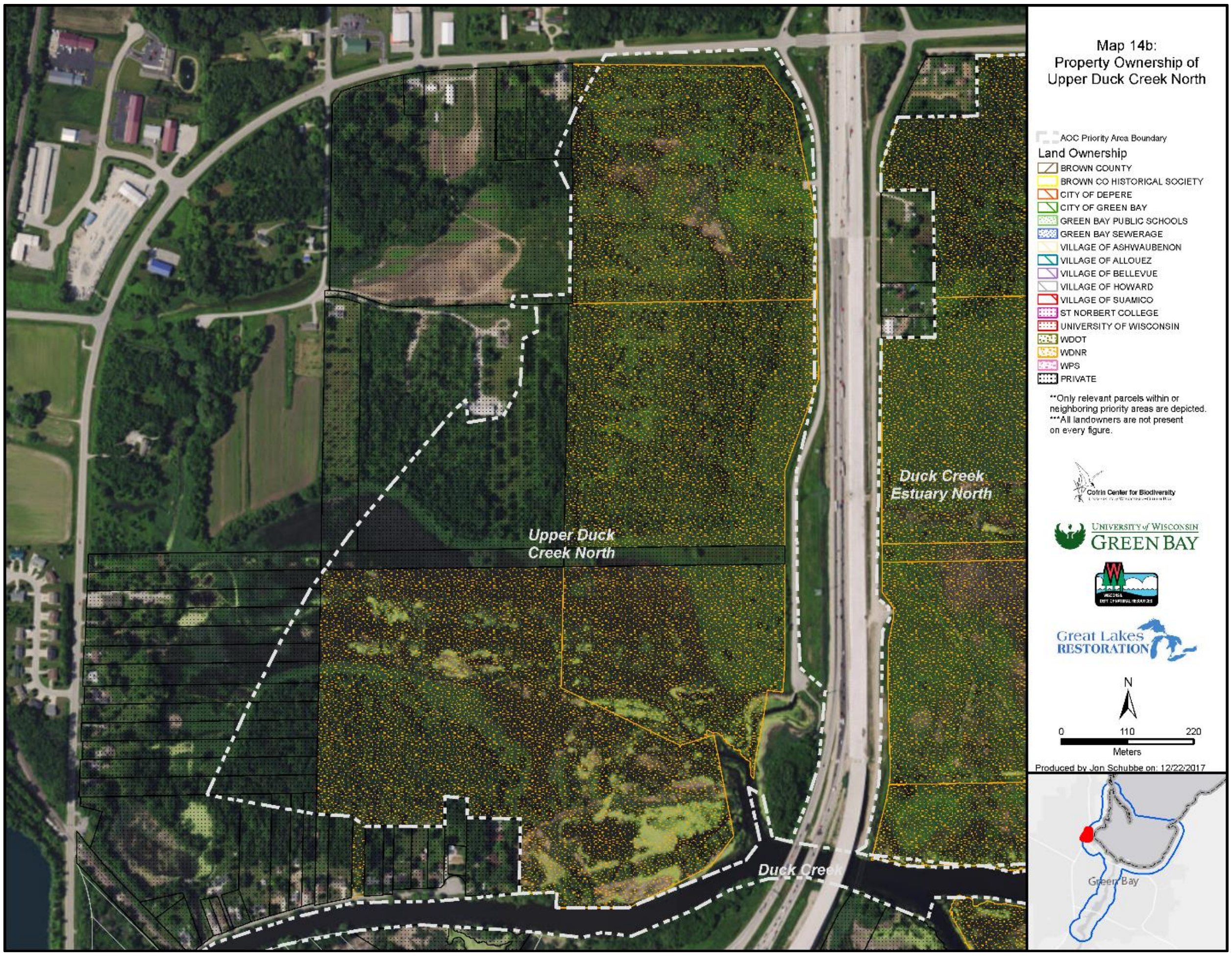
[36] Lower Fox River Watershed Monitoring Program: https://www.uwgb.edu/watershed/monitoring/overview.asp

[37] LGB&FR AOC Submerged Aquatic Vegetation Surveys 2017 – led by Dr. Amy Wolf and Dr. James Horn

Map of Upper Duck Creek North's 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. A small patch of southern sedge meadow was found by Dr. James Horn during the LGB&FR AOC 2016 plant biodiversity hotspot mapping and its general location is indicated by the yellow star below.



Land ownership boundaries at Upper Duck Creek North. Map made by UW-Green Bay’s Jon Schubbe.



Photograph of the Upper Duck Creek North priority area in the background, to the west of Interstate 41. The mouth of Duck Creek and Duck Creek Estuary North are shown in the foreground. Photograph taken by Erin Giese on 2 December 2016 facing northwest.