Final report to Michigan Sea Grant submitted by:

Donna Kashian[1], Avik Basu[2], Alisha Davidson[1], Joseph DePinto[3], Jason Duvall[3], Ray Fahlsing[4], Darrin Hunt[1], Frank Lupi[5], Bretton Joldersma[6]

Where People Meet the Muck:

An Integrated Assessment of Beach Muck and Public Perception at the Bay City State Recreation Area, Saginaw Bay, Lake Huron

1 Wayne State University (WSU), Department of Biological Sciences

2 University of Michigan

3 Limno Tech

4 Michigan Dept. of Natural Resources (MDNR), Parks and Recreation Division

5 Michigan State University

6 Michigan Dept. of Environmental Quality (MDEQ), Office of the Great Lakes

Table of Contents

Chapter 1: Introduction

Background

As detailed in historical Remedial Action Plans (MDNR 1988; MDNR, 1994), the Saginaw River and Bay was designated as a Great Lakes Area of Concern (AOC) for several factors including nuisance algal conditions that contributed to the Degradation of Aesthetics Beneficial Use Impairment (BUI). The deposition of organic debris ("muck') along the shores of Saginaw Bay has been a documented issue since the 1960s however there are other accounts that mention the muck problem as far back as the 1920s (Craig Stow, personal communication). Muck may be comprised of decomposing algae, macrophytes, phyto- and zoo-plankton, and can accumulate at levels sufficient to interfere with designated uses. Originally believed to be caused by excessive nutrient inputs, more recent evidence suggests that changes in the food web brought about by invasive species such as *Dreissenids* (i.e., zebra and quagga mussels) may also be a contributing factor by creating a condition in which the fraction of primary production attributable to benthic algae has greatly increased (MDEQ, 2012). Results from a 2008-2013 NOAA Multiple Stressor project suggest that muck composition differs in species content, varies across spatial and temporal scales, and can harbor high levels of fecal indicator bacteria (FIB) (Francouer et al. 2014). Muck has environmental, human health, economic and social impacts and as such requires an interdisciplinary, stakeholder engagement process to help clarify exactly how to address muck. Specifically, many technical and policy considerations need to be addressed to better understand the status of this BUI and feasible remedial actions that can be implemented given uncertainties related to the sources contributing to the problem. To address this multidisciplinary problem, this project used the Integrated Assessment (IA) approach to understand the muck issue and identify possible solutions for the Bay City State Recreation Area (BCSRA).

Integrated assessments are used to help decision-makers interpret and use the science surrounding complex environmental issues. These assessments work with stakeholders to understand an issue from various perspectives and identify the feasibility of potential solutions. Using outcomes of stakeholder groups as well as research, the assessment team then integrates natural and social scientific data to present outcomes that are not only useful but supported by all interested parties.

This IA process engaged a variety of stakeholders including federal, state, and local agencies; universities; Multiple Stressors technical experts; and, the Friends of the BCSRA (Appendix 5-B).

Stakeholders groups were committed to gaining shared knowledge on the causes and consequences of muck at the park, and where applicable, the Saginaw Bay region. Specifically, this IA project contributed to the current state of knowledge by focusing on the following outcomes:

1. **Environmental Modeling and Human Health Impacts** – Stakeholder involvement in the development of an improved and shared understanding of the human health implications, and environmental causes and consequences, of muck conditions at the park and in the Saginaw Bay region.
2. **Economic Impacts** – Assist stakeholders to better understand the economic costs and benefits of beach conditions and maintenance associated with various levels of muck at the park and in the region.
3. **Public Perception** – Develop a better understanding of stakeholder perception of the muck (and associated FIB), state agencies credibility to address the issue, as well as how public well-being is affected.
4. **Management Solutions** – Stakeholder involvement in the identification of acceptable short-term and long-term management actions that could alleviate the impact of muck at BCSRA and are appropriate considering the MDNR's resources and the current and future uses of the BCSRA.

Overview of the Saginaw Bay Beach Muck and Public Perception Integrated Assessment Process

This IA project summarized the current state of knowledge on the causes and consequences of muck conditions at the BCSRA, including the socio-economic aspects, and identified a series of feasible management actions that can be implemented at the park (and greater Saginaw Bay) to address both near- and long-term strategies. The primary objectives and associated methods included:

1. **Environmental Modeling and Human Health Impacts** - Synthesize the available data and research related to the origins of muck and its potential to harbor FIB, and evaluate how it behaves in the system and at the BCSRA. This primarily occurred through environmental modeling using a fine-scale linked hydrodynamic-sediment transport-advanced eutrophication model (SAGEM2) to track the fate and transport of sloughed *Cladophora* in the nearshore regions of inner Saginaw Bay including near the BCSRA.

2. **Economic Impacts** – Conduct economic analyses related to beach visitation and a BCSRA impact survey to understand how recreational values and park management are impacted by muck conditions.

3. **Public Perception** – Using a series of surveys and workshops, develop a better understanding of stakeholder perception of the causes of muck (and associated FIB), agency credibility, and impacts of muck on their well-being to inform agency management strategies.

4. **Management Solutions** – During two workshops involving technical experts, agencies, and local stakeholders, assess previous management actions and identify any new management scenarios to address muck-related issues at the park.

To address these four objectives, stakeholder engagement was an overarching priority throughout the entire IA process. The role of stakeholders included providing strategic direction, input, and feedback on all aspects of the project, as well as being involved with the identification of recommended solutions. The targeted audience included key decision makers from local, state, federal, and non-government organizations in the region, as well as individuals with a strong interest in the muck-related issues at the park and in the bay. The goal of the project was to obtain input from and share knowledge with stakeholders to have the recommended solutions of the IA considered in local decision making efforts. This project facilitated stakeholder engagement through individual stakeholder communications (i.e. in person, email and phone) and project workshops.

The IA project put together four Focus Groups for each of the theme areas (i.e., Environmental, Economic, Social and Management). These groups included technical experts, parties from the MDNR, MDEQ, USGS, universities, county officials and individuals with expertise and knowledge on the theme areas. The aim for members was to input and feedback on the content, process, and outcomes.

In addition to the workshops as part of the public perception component, the IA project held two management-focused workshops. The workshops included a session for a broad group of stakeholders to engage in the project and a more selective, invitation-only session with key stakeholders possessing some knowledge and/or expertise on the muck-related subjects. Specific goals of the first workshop were to clarify and better define, if necessary, the IA question and begin to identify potential options to address the muck issue and inform decision making. The objectives of the workshop were to: 1) disseminate information on what is known on muck and algal research; 2) identify educational needs as it relates to muck; 3) solicit inputs from park managers; 4) define stakeholder roles; 5) identify data gaps; 6) identify additional data sets; 7) identify additional economic data regarding costs and impacts of muck, physical muck removal programs, and nutrient abatement programs; and 8) update stakeholders on the status of the project by highlighting the work that has been completed. The second workshop again included two sessions; one for broad audience participation and project updates, and a more focused session with project PIs (e.g., modeling and socio-economic survey teams), Focus Group members, and other interested stakeholders. This workshop summarized project findings to date, including any modeling and survey data collected and synthesized that may help inform stakeholders of potential management and policy actions that can be considered feasible. The outcome of the second workshop was a refined suite of recommended actions that can be further explored by the IA Team.

Key Findings

Key outcomes of this project are grouped into four themes, with additional detail in Synthesis.

Environmental Modeling and Human Health Impacts

- Even drastic reductions in external phosphorus loads will not result in complete elimination of Cladophora growth in the inner bay.
- Increased water levels can limit the area extent of Cladophora growth due to light limitation.
- The Saginaw River provides approximately 82% of the TP load to the bay, however other smaller tributaries can have important influences on localized regions near their mouths.

Economic Impacts

- The data and economic models of beach visitation predicted that the Huron South region (which contains the BCSRA and 41 other beaches) receives just under 7% of the beach visits in the lower peninsula of Michigan and the BCSRA receives about 8% of the predicted trips to its region.
- From the overall data and the modeling results, it was clear that all else equal, beachgoers prefer Great Lakes beaches in other regions, especially beaches on Lake Michigan—beaches in the Huron South region had the lowest baseline visitation of any region.

- Despite the general preference for beaches in other regions, the results suggest that improvements in water quality in the Huron South region would yield significant economic benefits to beachgoers and increase the economic impacts of trips to the region, though the region's beaches would likely remain less popular than the Lake Michigan regions or the Southeast Michigan region.

Public Perception

- Citizens and agencies believe that they disagree about the various causes of beach muck, but both groups rated some causes (i.e., ecosystem factors and nutrient loading) similarly. While citizens did feel wastewater discharges were a stronger contributor, these results suggest a shared understanding about some underlying causes.
- Citizens expressed strong concerns about the negative impact beach muck has on park visitation, local economic activity, community well-being, and aesthetics. While agencies did view these impacts as less important, there was evidence that in some cases agencies do have a deeper appreciation for these concerns than citizens might realize or give agencies credit for.
- With few exceptions, citizens viewed all management strategies more positively in terms of effectiveness and practicality than agency representatives. This discrepancy speaks to the strong desire among citizens to see management action and the uncertain impact of management efforts perceived by agency representatives.

Management Solutions

- Improved beach aesthetics have resulted from manual removal of macrophytes, including hand raking and costly beach cleaning machines, which will likely be reflected in beach tourism and attendance.
- These strategies are palliative and only work for a short period.
- **Recommendation**: Given that beach muck appears to be a historical part of the system and that nutrient reduction most likely won't prevent muck from fouling Saginaw Bay beaches, we recommend diverting resources from beach cleaning efforts that attempt to achieve bare sandy beaches, and instead focusing resources on emphasizing alternative ecological attractions such as the local wetlands.

Chapter 2: Environmental and Human Health Impacts and Modeling

To start this IA assessment, current environmental and human health research was synthesized to better understand the issue and identify any additional environmental, economic, social, and management actions can be taken to more fully examine the problem in a focused area within Saginaw Bay. In particular, a literature review detailing human health impacts imposed by muck, and the development of an environmental model to predict muck levels and thus associated impacts, were completed (full bibliography in Appendix 2-A). Environmental modeling was used to understand the muck and FIB dynamics, as well as the limitations of the system in its current state in an effort to bring about a collective understanding of the causes, consequences, and interim solutions to the problem. To this end, LimnoTech used their fine-scale linked hydrodynamic-sediment transport-advanced eutrophication model (SAGEM2) to track the fate and transport of sloughed *Cladophora* in the nearshore regions of inner Saginaw Bay including near the BCSRA, hence capturing its potential contribution to formation and distribution of muck at the park. *Cladophora* is only one of several algae species that constitute muck, hence it served as a surrogate for the linkage between phosphorus loading and muck-forming benthic vegetation growth and eventual wash-up on shore. The modeling effort used this species as a surrogate for all benthic algal growth because the model currently has the capacity to predict its development and fate through the system. The information on the timing and quantity of material washing up on the BCSRA shoreline was then used to corroborate the model simulations. The model was also able to pinpoint when conditions are favorable for material/muck to wash up on the beach due to wind and wave conditions.

Human health impacts

Escherichia coli and enterococci are fecal indicator bacteria (FIB) commonly used in beach monitoring to provide a measure of microbial pollution in recreational waters due to their links to gastrointestinal illness (Verhougstraete et al. 2014). The presence of muck in littoral and shore areas along recreational beaches has become a serious human health concern because many studies have shown algal mats provide a suitable habitat for the growth and persistence of bacteria such as *E. coli*, enterococci, *Shigella*, *Campylobacter*, and *Salmonella* (Byappanahalli et al., 2009; Ishii et al., 2006; Verhougstraete et al., 2010 in Verhougstraete et al. 2014). Sediments have also found to harbor increased concentrations of FIB (E. coli concentrations up to 40 times higher in nearshore sediment compared to overlying water (Alm and Burke, 2003; Whitman and Nevers, 2003 in Verhougstraete et al. 2014). The exact causes and mechanisms of these associations are not well understood, but recent research has attempted to elucidate the relationships.

In a study of Saginaw Bay beaches, Verhougstraete et al. 2014 found several trends. First, E. coli and enterococci were highest in algal mats and sediment. Two alternative indicators, C. perfringens and coliphage, also accumulated in these zones. E. coli, enterococci, C. perfringens, and coliphage levels were routinely 1 log greater in sediments than shallow water, regardless of algal mat presence. The study also demonstrated that elevated bacteria in shallow waters were related to concentrations of bacteria in the sediment and algal mats. Previous studies suggest that this presence may not be due to recent influx of fecal materials, but may be legacy contamination that persists in sediments and algal mats (Byappanahalli et al., 2003, 2009; Englebert et al., 2008a; Ishii et al., 2006 in Verhougstraete et al. 2014). Overall, this study verified sediment and algal mats act as nonpoint sources of bacteria, although it failed to routinely identify the source of fecal contamination using molecular source tracking methods.

In a study of beach wrack (the pile of material that washes ashore and collects along a beaches tideline) from nine Great Lakes beaches, Nevers et al. (2016) found high concentrations of E. coli at multiple locations across all seasons sampled (early spring, summer, and late fall). The study also found that mechanical grooming of the shoreline did not decrease overall E. coli associated with beach wrack: the median concentration of E. coli in shoreline wrack collected from regularly groomed beaches was 3.45 log10 MPN/g dw and from ungroomed beaches was 3.34 log10 MPN/g dw. At locations where beach wrack remained undisturbed, E. coli concentrations also remained high through the summer season. This may indicate either continuous inoculation with fecal material from birds, which are frequently seen picking though beach wrack in search of food, or increased E. coli persistence and/or growth in the presence of this material. Higher concentrations of E. coli were found in wetter shoreline wrack, and high concentrations of E. coli were released during rinsing experiments (with 61-87% released in first rinse), suggesting that loosely attached E. coli were abundant. This may contribute to the often-seen spike in FIB following rainfall events.

A study in California (Russell et al. 2014) found that beach grooming of wrack associated with FIB saw either no change or increase in FIB concentrations, with additional impacts of beach grooming including surf zone turbidity and silicate, phosphate, and dissolved inorganic nitrogen concentrations. The findings suggest that beach grooming for wrack removal is not justified as a microbial pollution remediation strategy.

While no human mortality or morbidity events have been directly linked to enteric bacteria found at recreational beaches in the Great Lakes, frequent beach closures remind both managers and beachgoers that this remains a possibility. Until additional research better identifies the source of the FIB, water and sediment monitoring, with beach closures as necessary, remain the only management tools to protect human health.

Environmental modeling: Saginaw Bay Ecosystem Model (SAGEM2)

As part of the NOAA-led Saginaw Bay Multiple Stressors Project, LimnoTech had previously developed a 3-dimensional advanced aquatic ecosystem model, known as the Saginaw Bay Ecosystem Model (SAGEM2). The SAGEM2 framework, synthesizes recent water quality data and simulates a complete nutrient and phytoplankton mass balance for the bay. SAGEM2 is a linked hydrodynamic-lower food web model, which also simulates sediment transport and wave induced resuspension. The overall conceptual framework of the model and linkages to meteorology, hydrology, and hydrodynamics is shown in Figure 2.1.

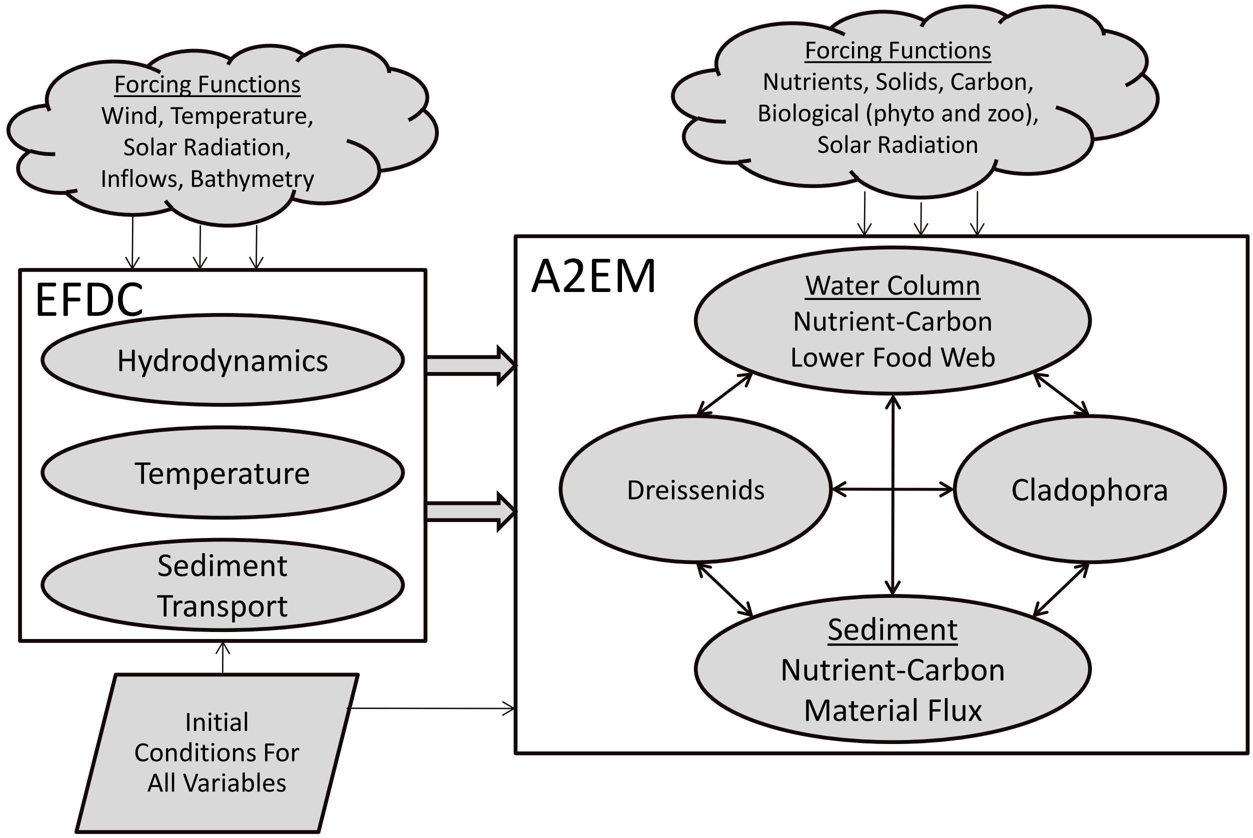


Figure 2.1. SAGEM2 conceptual framework.

The kinetic formulations in the model are comparable to other "state-of-the-science" water quality models, such as CE-QUAL-ICM and CAEDYM. SAGEM2 can simulate up to 5 classes of phytoplankton, 3 classes of zooplankton, as well as refractory, labile, dissolved and particulate forms of phosphorus and nitrogen. The model also includes feedback mechanisms with 2 classes of dreissenids, and a benthic algal class (e.g., Cladophora). Viable, floating detritus, and deposited forms of benthic algae are tracked within the model spatially and temporally. The source and sink pathways for phosphorus cycling are shown in Figure 2.2.

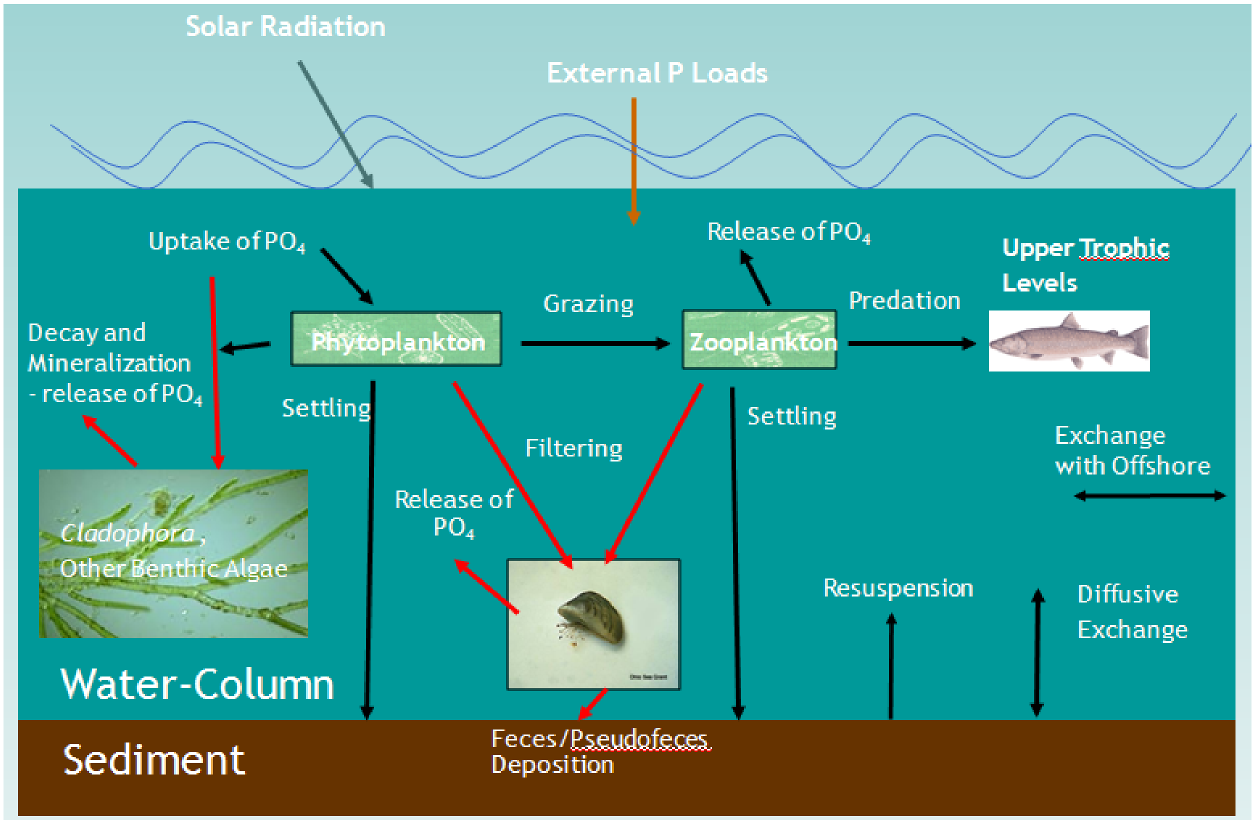


Figure 2.2. SAGEM2 conceptual framework.

The computation grid for SAGEM2 is shown in Figure 2.3. The grid consists of about 747 horizontal cells of equal size (2 km x 2 km). The vertical dimensionality of the model varied spatially, with up to 10 vertical layers in the deepest regions, and as few as 1 layer in the shallowest areas.

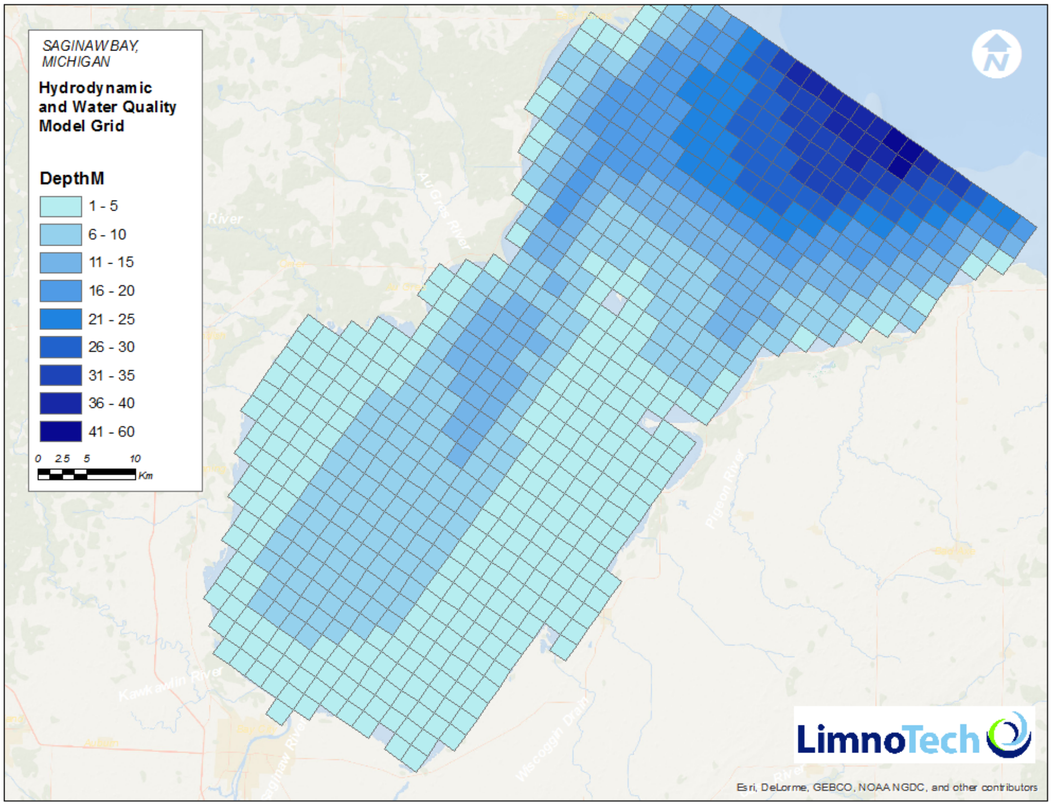


Figure 2.3. SAGEM2 computational grid and bathymetry.

An updated model grid was developed to assess the more local fine-scale impacts of the main tributaries to the bay. This grid (Figure 2.4) consists of 2792 horizontal cells of equal size (1km x 1km), while the vertical dimensionality remains the same as the 2km grid. Both grid configurations were used in this modeling analysis.

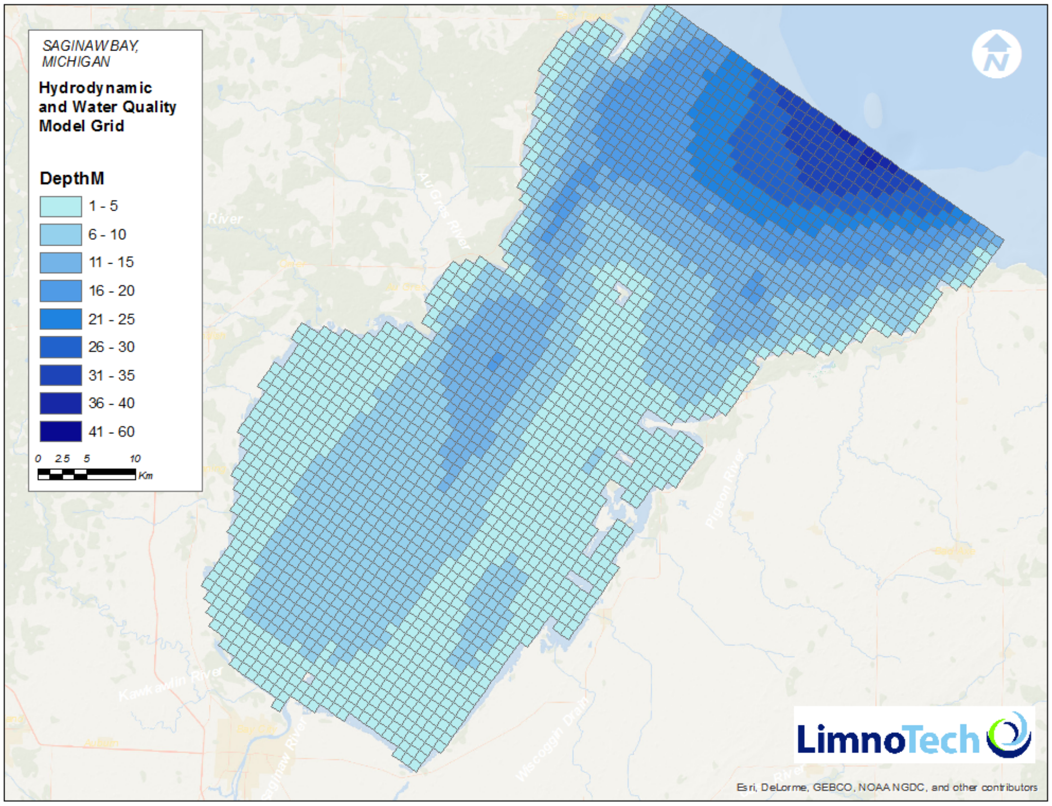


Figure 2.4. Revised 1km fine-scale computational grid and bathymetry.

Applications of the SAGEM2 Model

The SAGEM2 model was applied in several scenarios to assess the bay response to multiple parameters, such as tributary loading, mussel density, and water levels. These applications are described below.

Existing conditions, 2009 and 2010 simulations

The model was calibrated to existing conditions from 2009-2010. Data from several sampling stations were including in the calibration process (Figure 2.5) to ensure appropriate model estimates for the entire bay. Stations 2 (Saginaw River mouth) and 5 (western shore) are circled in Figure 2.5, and model total phosphorus (TP) and chlorophyll-a (CHL) calibration figures are presented below for these locations (Figures 2.6 – 2.9).

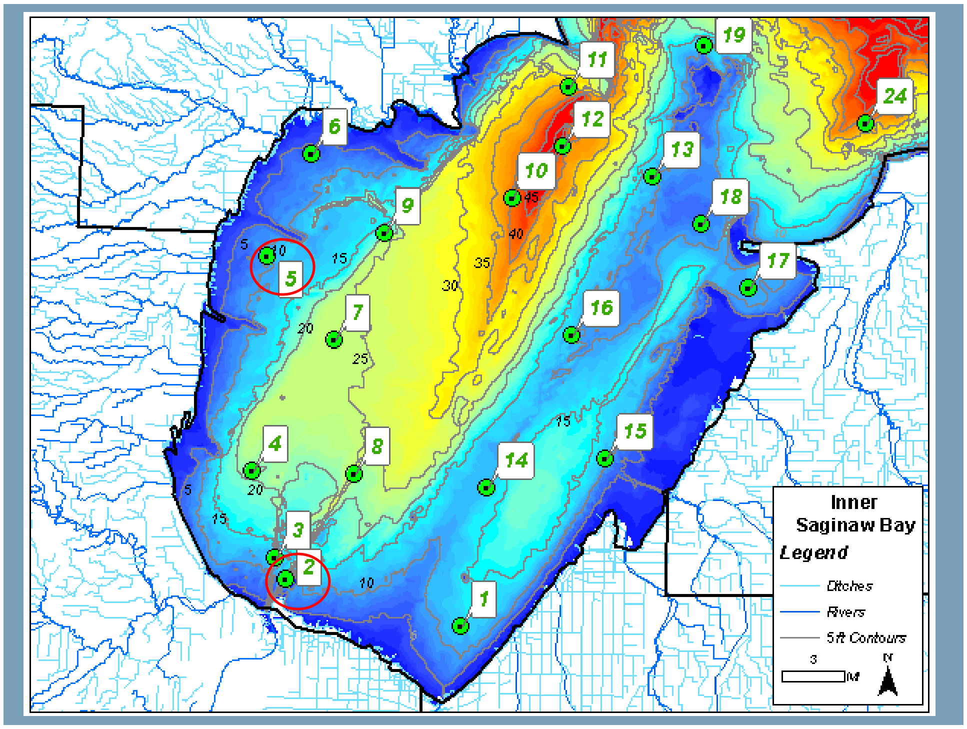


Figure 2.5. Location of monitoring stations.

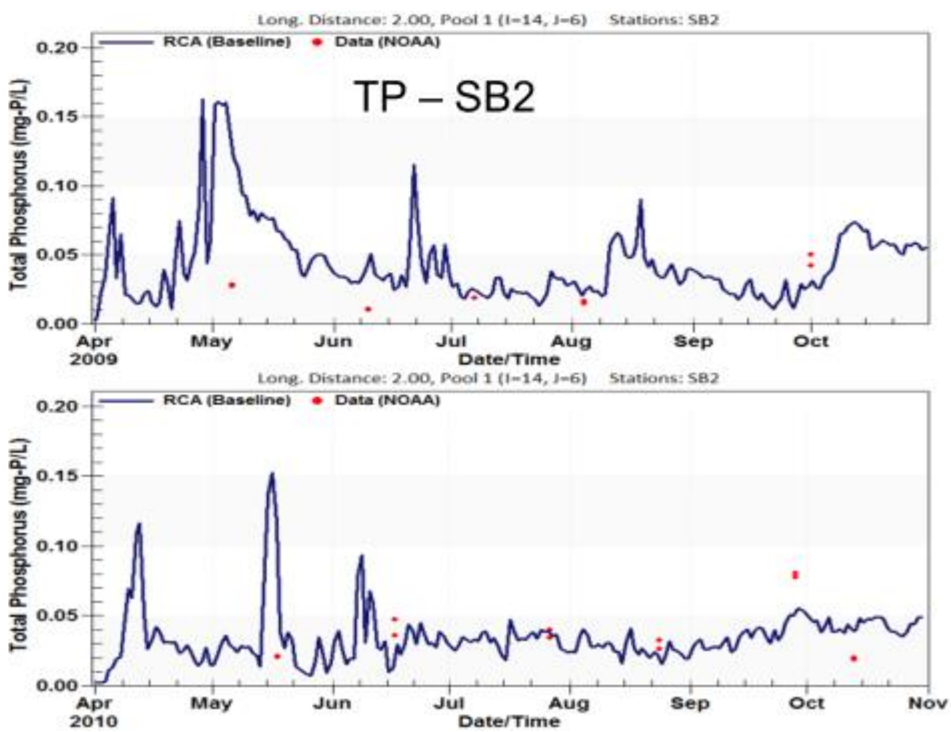


Figure 2.6. TP calibration time-series for station SB2, near Saginaw River mouth (top panel: 2009, bottom panel: 2010).

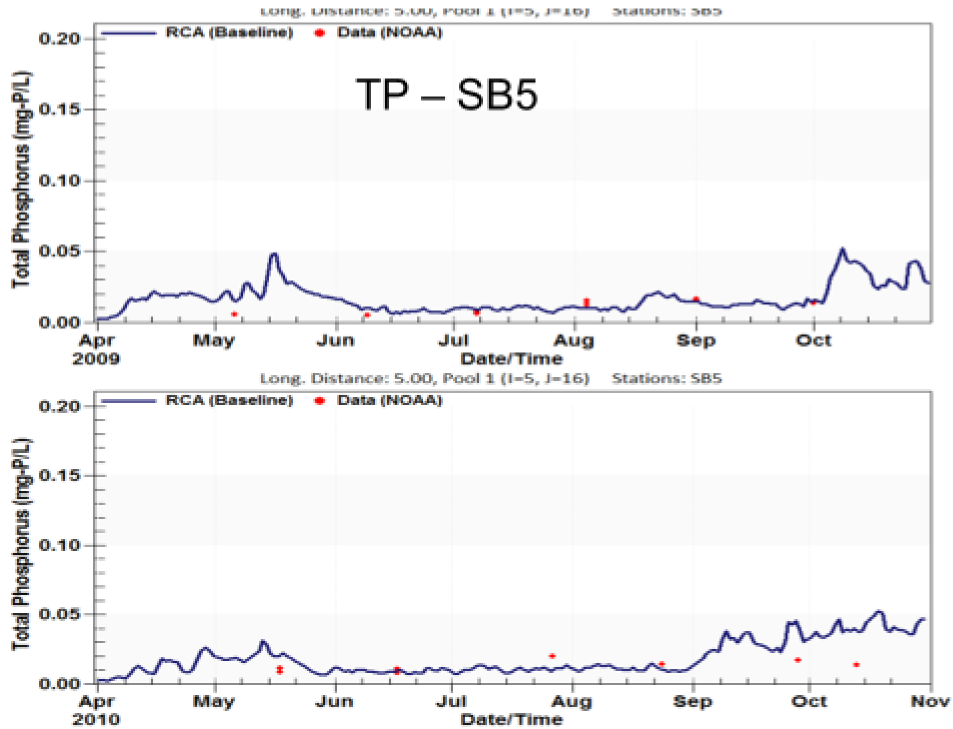


Figure 2.7. TP calibration time-series for station SB5, near western shore of bay (top panel: 2009, bottom panel: 2010).

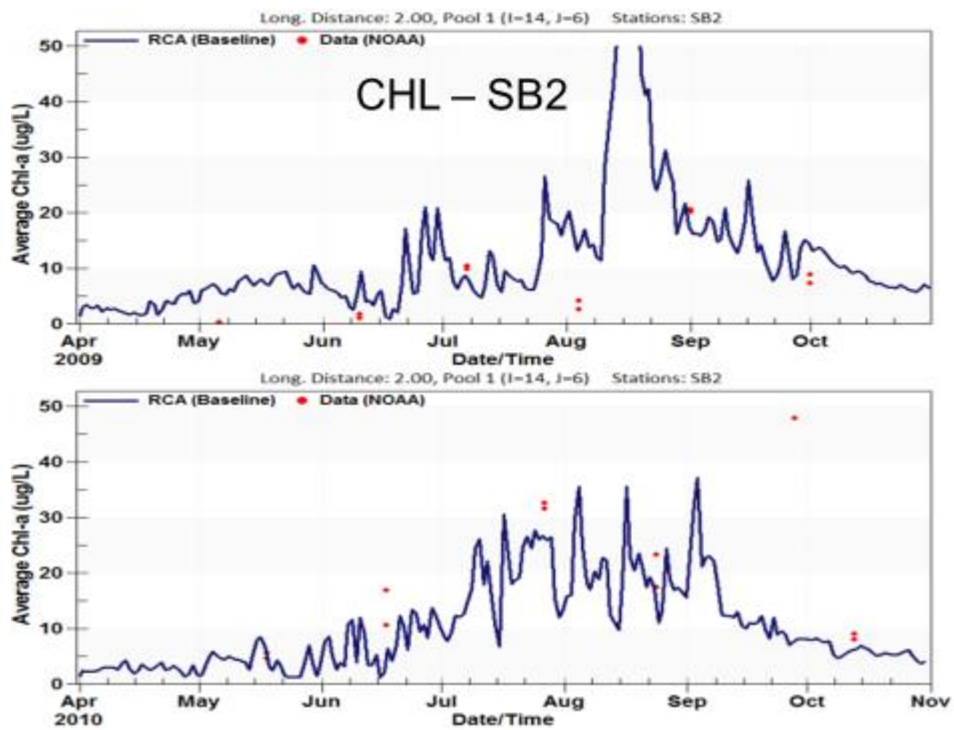


Figure 2.8. Chlorophyll-a calibration time-series for station SB2, near Saginaw River mouth (top panel: 2009, bottom panel: 2010).

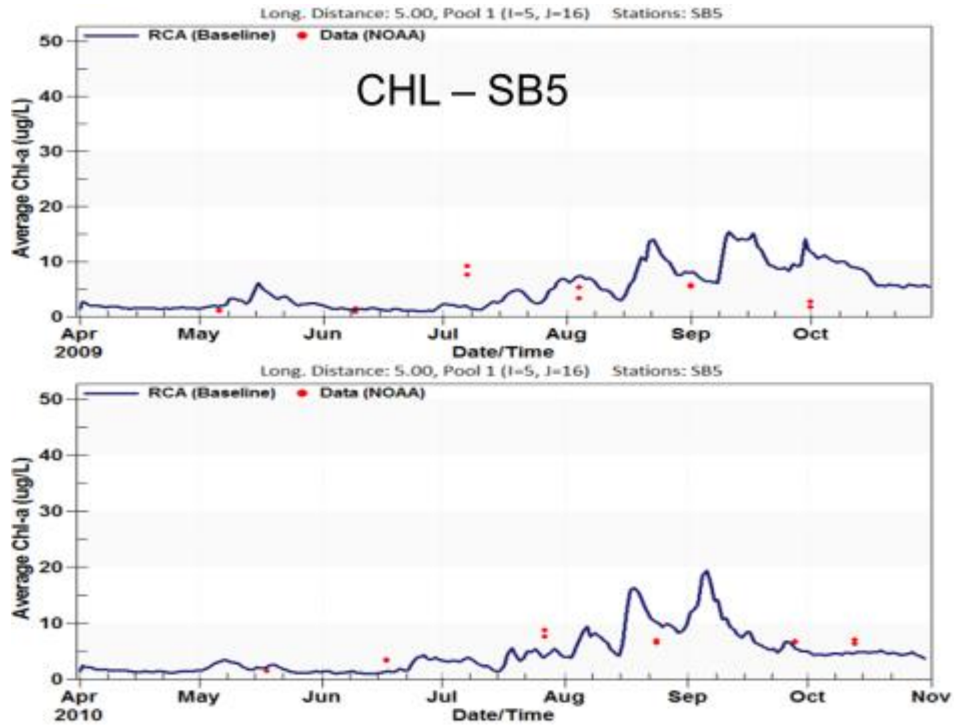


Figure 2.9. Chlorophyll-a calibration time-series for station SB5, near western shore of bay (top panel: 2009, bottom panel: 2010).

A map showing the model estimated Cladophora biomass growth for mid July 2009, under baseline conditions, is shown in Figure 2.10. This map demonstrates that the Cladophora growth is generally constrained to depths and sediment conditions that can support the algae. The deeper portions of the inner bay show little to no growth, as the light does not penetrate deep enough in this zone. Further, the peak growth corresponds to the zone directly adjacent to the mouth of the Saginaw River, where nutrient loads are the highest.

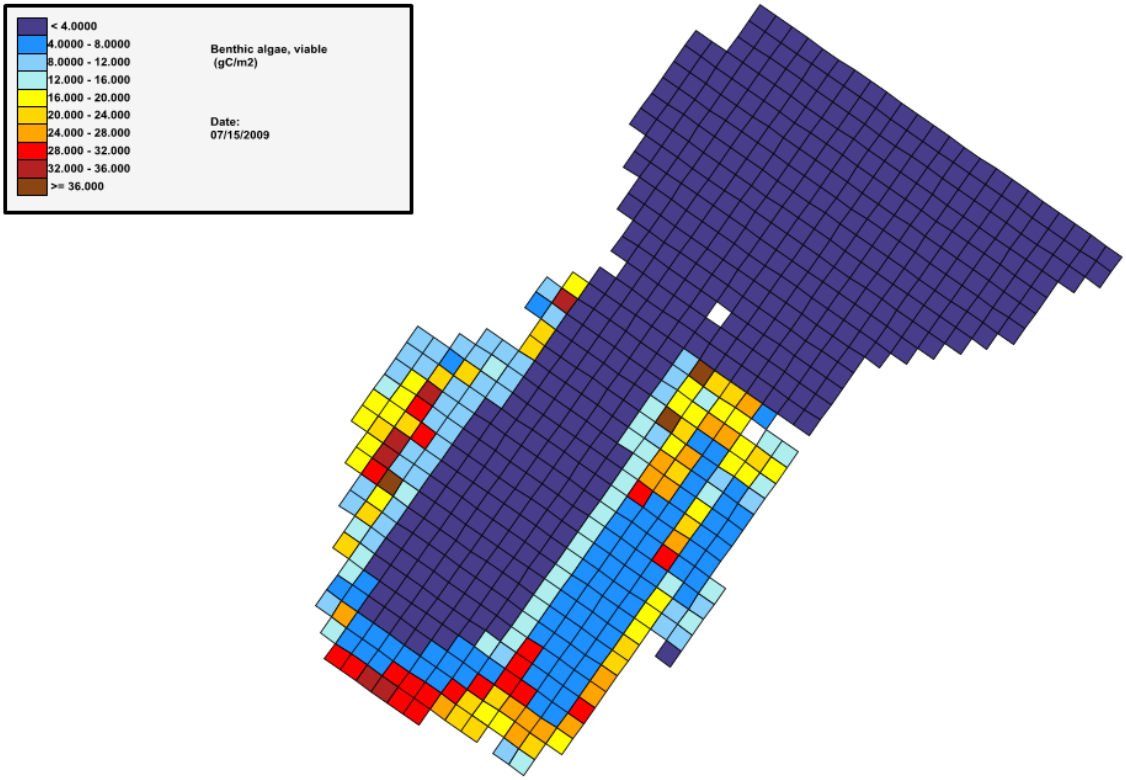


Figure 2.10. Model estimated viable Cladophora biomass on July 15, 2009, under baseline conditions.

Floating Cladophora detritus is show in Figure 2.11 at a time 2 week after the viable biomass shown in Figure 2.10. The “muck” will vary spatially and temporally with the flow patterns and wind direction in the inner bay, but generally accumulates along the shore lines on the eastern and western edges of the inner bay.

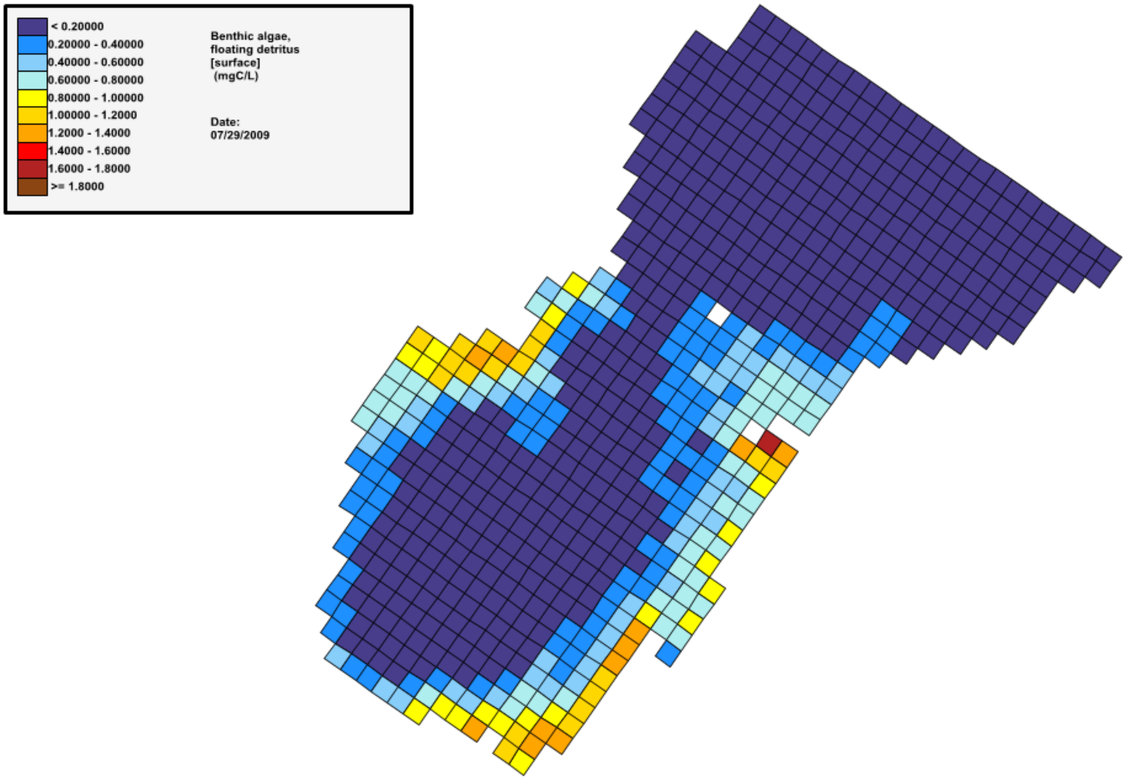


Figure 2.11. Model estimated floating detrital Cladophora (muck) on July 29, 2009, under baseline conditions.

Hypothetical extreme phosphorus load reduction scenario

As part of the modeling analysis, we used SAGEM2 to simulate conditions in the water column under hypothetical loading reductions. As an extreme scenario, we developed a scenario where all the total phosphorus entering the bay from the Saginaw River was removed. That is, the TP load from the Saginaw River was set to zero, while still allowing the natural hydrology from the river toe affect the circulation dynamics in the bay. All other state variables remained the same as the baseline "calibration" conditions. Additionally, the sediment bed characteristics, including stored nutrients and fluxes were unchanged. This internal source of phosphorus can still stimulate Cladophora growth, even with little external load contribution, as ween in Figure 2.12. While the very local growth near the mouth of the river was significantly reduced, the overall inner bay growth was not as sensitive (Figure 2.13) and the spatial average shows that Cladophora can still thrive in the inner bay, even with significantly reduced external nutrient loads.

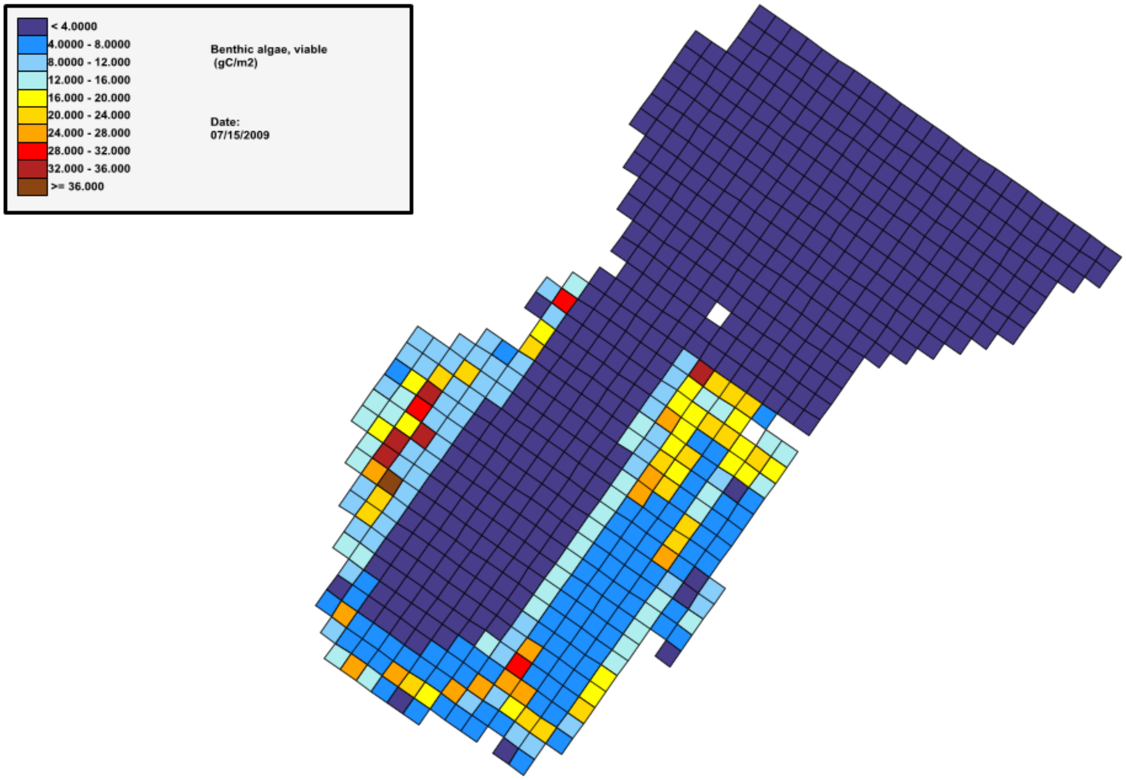


Figure 2.12. Model estimated viable Cladophora biomass on July 15, 2009, with no TP load from the Saginaw River.

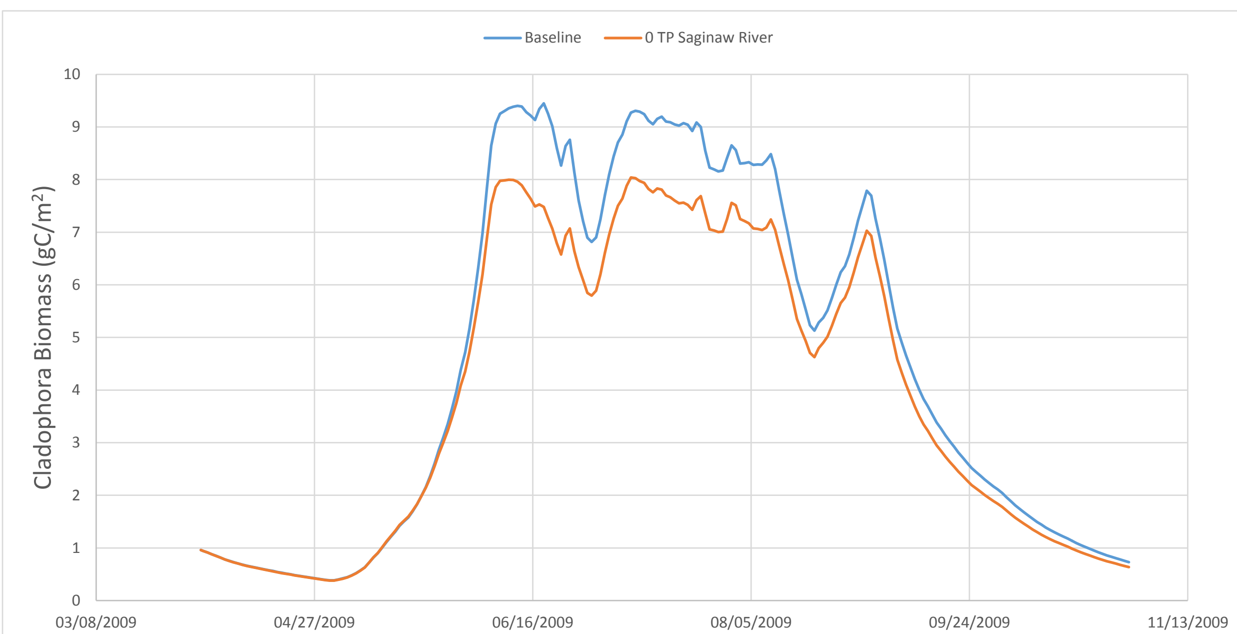


Figure 2.13. Model estimated viable Cladophora biomass, averaged over the inner bay, 2009.

Analysis of major tributary contributions

As described in the loading reduction scenario above, the influence of tributary loads can have very localized influences on algal growth, particularly benthic algae. The SAGEM model contains 26 individual tributaries, however, the Saginaw River is by far the most dominant source, contributing approximately 82% of the external total phosphorus load. However, the impact of the Saginaw River can vary significantly spatially within the bay.

We used the fine-scale 1km SAGEM2 model to perform relative contribution analyses of each tributary, towards each model grid cell, by running the model with each tributary individually with baseline boundary conditions, and all other tributaries have only inflow and no concentration. This allowed us to map the relative contribution of each tributary to each model cell. Figure 2.14 shows the influence of the Saginaw River, with the left panel showing the influence on each cell, if only the Saginaw River is included in the analysis. The right panel shows the influence of the Saginaw River, under baseline conditions; i.e., all tributaries are included. Figure 2.14 clearly demonstrates that the Saginaw River is the most influential contributor to the majority of the model domain, however, other tributaries can be more important in local regions at their associated mouths. For example, the Rifle River dominates the influence directly near its mouth, as seen in Figure 2.15. Again, the left panel shows the cells that are most influence by the Rifle River if it is the only tributary included in the analysis; while the right panel shows its influence when all tributaries are included. Even though the Rifle River has little influence on the majority of the model domain, the local cells near the mouth are heavily influenced by it. A similar set of plots are shown for the much smaller Pigeon River on the eastern side of the bay. Even though the Pigeon River watershed is heavily agricultural, its influence on nutrient loading to the bay is minimal do to the size of the watershed and flow.

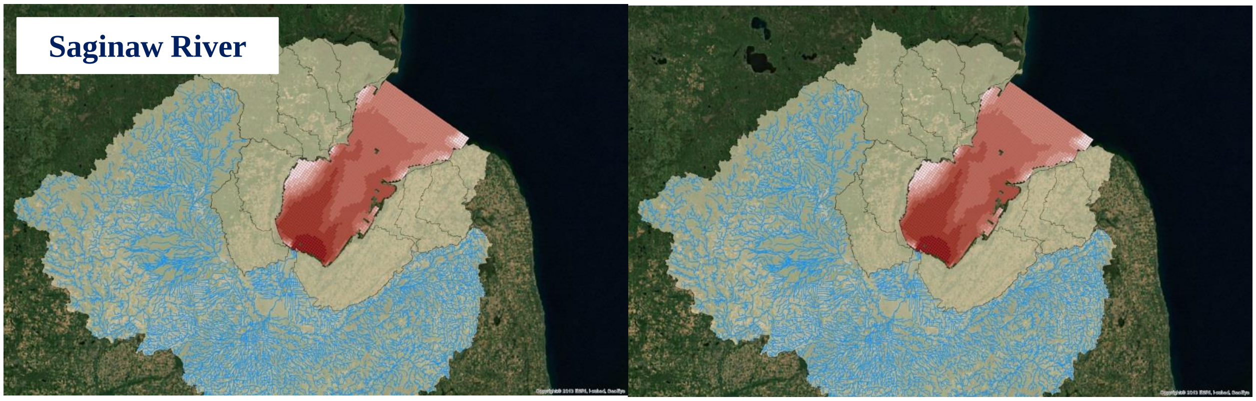


Figure 2.14. Relative contribution of Saginaw River to each 1km model grid cell. (left: cell contribution with only Saginaw River inflow; right: cell contribution with all tributary inflows.)

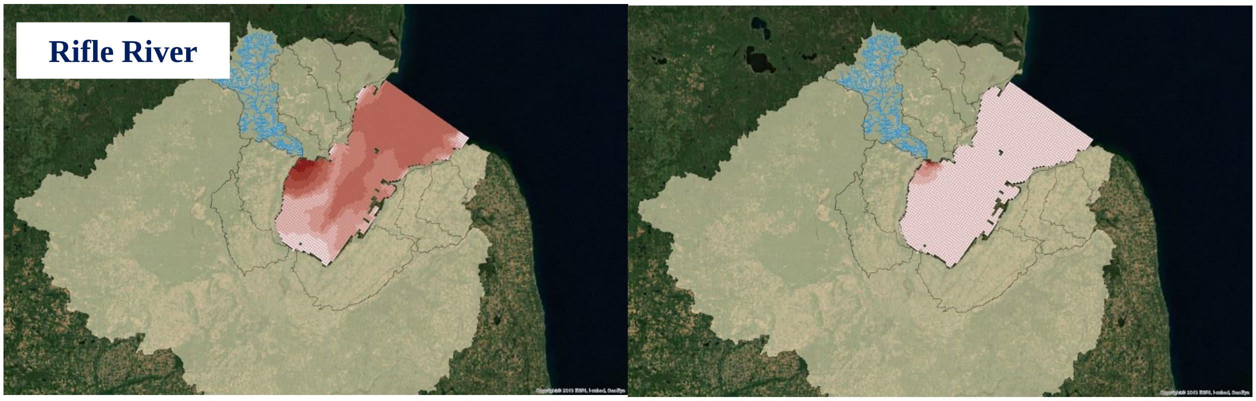


Figure 2.15. Relative contribution of Rifle River to each 1km model grid cell. (left: cell contribution with only Rifle River inflow; right: cell contribution with all tributary inflows.)

Figure 2.16. Relative contribution of Pigeon River to each 1km model grid cell. (left: cell contribution with only Pigeon River inflow; right: cell contribution with all tributary inflows.)

Even though Figure 2.14 shows that the Saginaw River inputs to the model dominate the majority of the cells, the modeling analysis based on an extreme hypothetical load reduction from the Saginaw River would not have as dramatic impact on Cladophora growth as anticipated. The role of internal phosphorus loading from the sediments remains important in the near shore areas where

Cladophora growth is most significant. However, if TP loading from the Saginaw River were permanently significantly reduced, eventually the sediment nutrient flux would reach equilibrium with the new external loads. The time frame for the system to reach equilibrium could be on the order of decades. Such an analysis is outside of the scope of this effort, however.

Hypothetical Water Level Increase

The SAGEM2 model was originally developed and calibrated for the years 2009-2010. However, more recent years have seen an increase in water levels in the Great Lakes. Increased depth in Saginaw Bay would theoretically reduce the amount of substrate that experiences proper light conditions for Cladophora growth, however, other considerations such as water column filtering and nutrient cycling via dreissenids (e.g., the "near shore shunt" hypothesis) may have also increased light penetration in the bay.

We used the SAGEM2 model to run a hypothetical scenario where water levels have increased by 0.5m throughout the bay. This increase corresponds to more recent water level conditions. No other model parameters where modified in this simulation; it was intended to simply investigate the potential reduction in available light conditions in the substrate in the model. Figure 2.17 shows a map of simulated detrital Cladophora in late-July in the bay for the baseline condition (left panel) and increased water lever condition (right panel). The differences between the scenarios are not very drastic, although the area is reduced in the high water level scenario. The similarities in the simulations are likely a result of the model being calibrated for the lower water conditions, and the increase in depth did not significantly alter the light penetration-depth relationship.

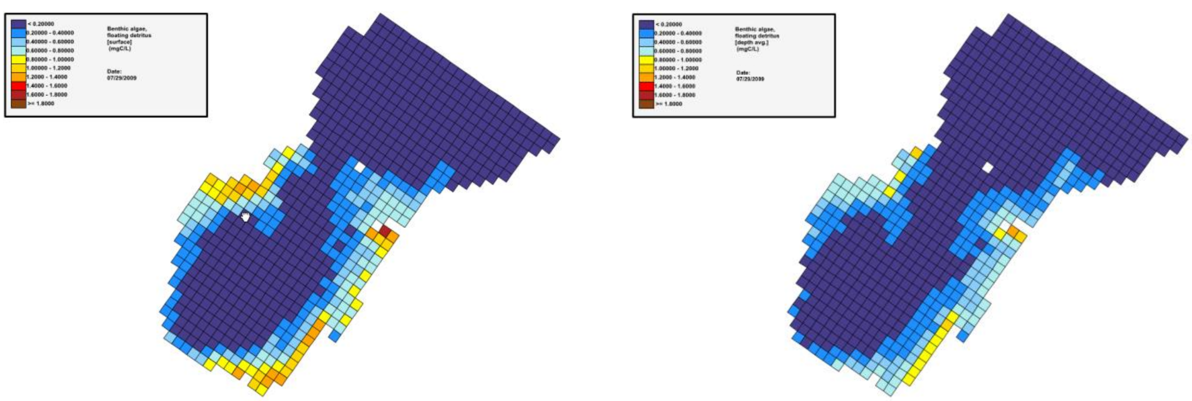


Figure 2.17. Comparison of summer Cladophora detritus (left: baseline scenario; right: 0.5 m water level increase from baseline scenario.)

Saginaw Bay Wind Analysis

The SAGEM2 model is useful for studying inner bay wide lower food web dynamics, and can inform managers and stakeholders on potential water quality responses to hypothetical scenarios related to loading and hydrometeorological changes. However, the spatial resolution, even using the revised 1km grid, is too coarse to assess impacts on beach level scales. The model can provide insight on the overall growth and transport patterns, but it is not appropriate to assess the impact of barriers and retention nets of sizes on the order of meters.

However, we can assess the potential impacts of such structures via alternate analyses to gain a high level view of expected outcomes.

NOAA-GLERL Fine-Scale Forecasting Model

One useful tool is the real-time NOAA-GLERL Saginaw Bay Model, which is “operational” (i.e., it is automated and constantly updated) with results posted to the web (https://www.glerl.noaa.gov//res/glcfs/sb/) four times each day in a predictive 48hr “Nowcast.” The model publishes very fine scale surface and depth averaged currents, temperatures, and wind speed and direction. It is also linked to a particle tracking model that simulates the transport pathways of hypothetical particles released from the Saginaw River mouth. An example map of the potential concentration of semi-buoyant particles from the model is shown in Figure 2.18. This figure shows the simulated location of particles released continuously from the Saginaw River. Figure 2.19 shows a companion map that displays the vertical location of the released particles. The NOAA-GLERL forecasting and nowcasting model can be used to predict short term transport pathways in an extremely fine scale model domain. This model does not simulate biological growth or nutrient cycling, it simply is “tracking” model that simulates flow patterns based on wind speed and directions and Saginaw River hydrology. However, as the peak Cladophora growth is generally stimulated by the nutrients from the Saginaw River, the model can be used a surrogate to help determine potential locations of muck and floating detritus.

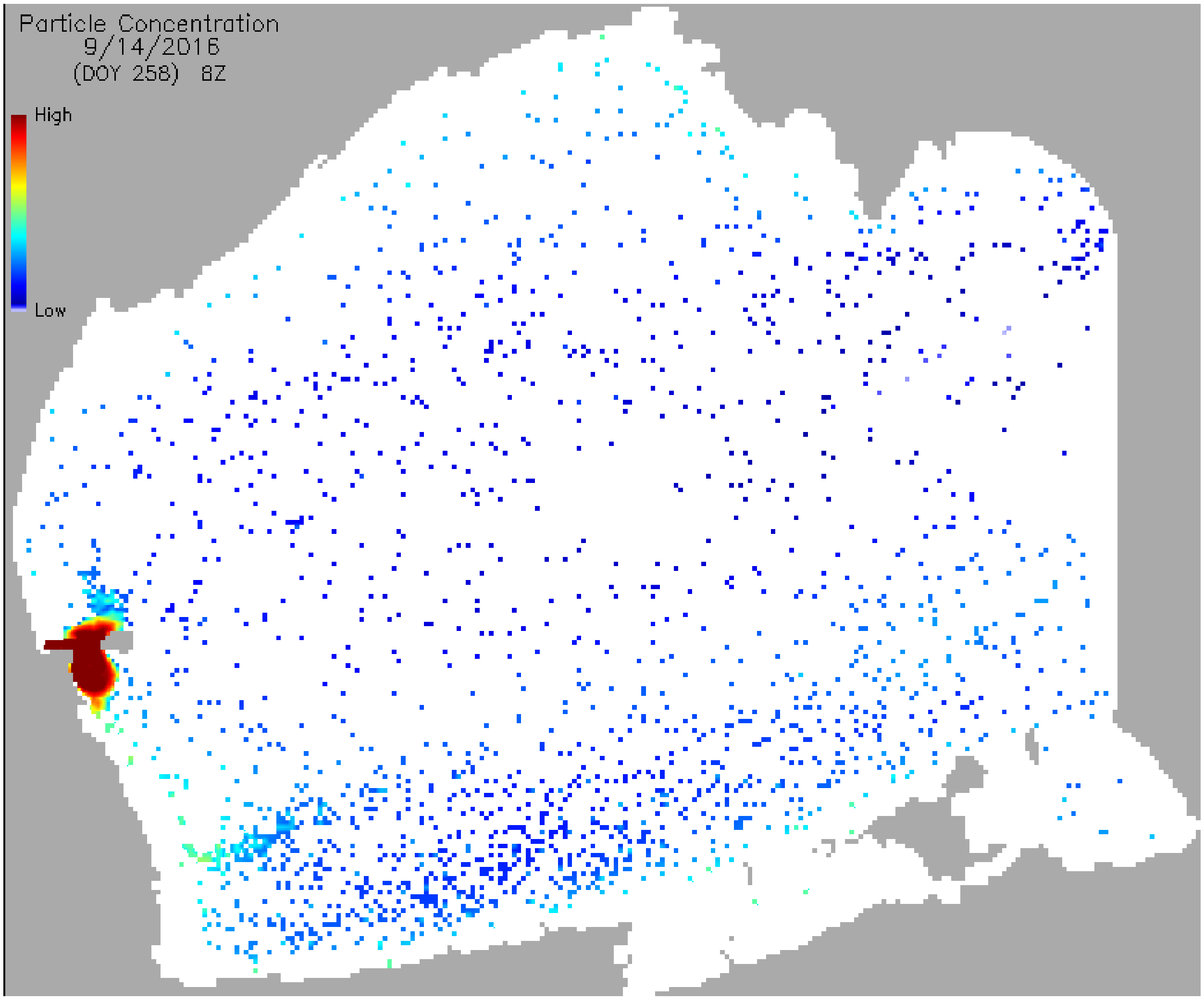


Figure 2.18. NOAA-GLERL Saginaw Bay Forecasting Model predictions of surface concentration of hypothetical continuous particle release from the Saginaw River.

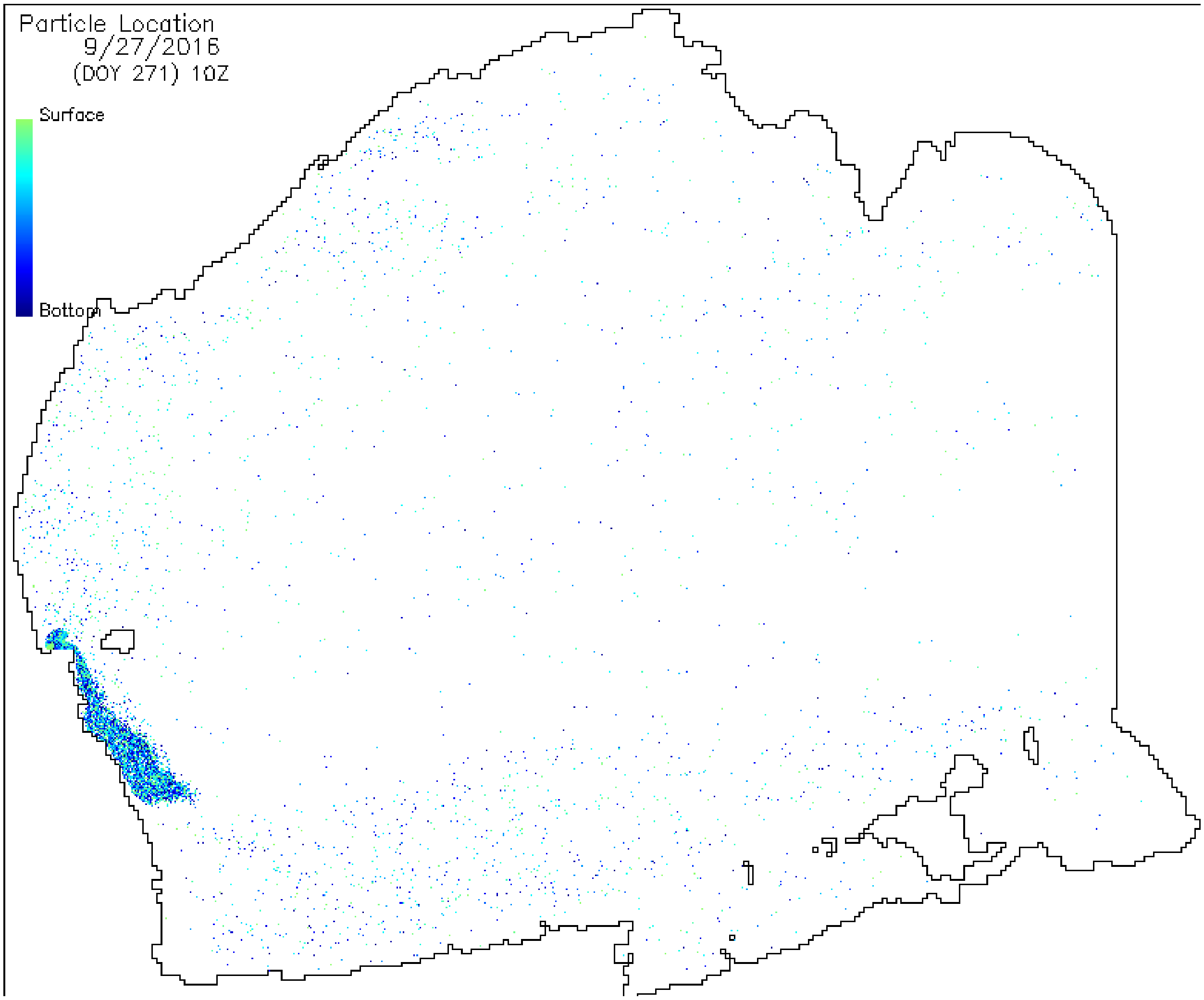


Figure 2.19. NOAA-GLERL Saginaw Bay Forecasting Model predictions of vertical distribution of hypothetical continuous particle release from the Saginaw River.

Dominant Wind Patterns

The NOAA-GLERL forecasting model for Saginaw Bay is highly dependent on wind conditions, as the particles that are released will follow the water currents and trajectories predicted by wind conditions. It is therefore also important to assess the dominant wind direction during the recreational season around Saginaw Bay. Nguyen et al. (2014) recently published an extensive data and modeling review of currents and circulation patterns in all of Lake Huron, as well as locally in Saginaw Bay.

The wind rose plots shown in Figure 2.20 display the dominant wind direction for July, August, and September for 2009 – 2011. The data is displayed in a manner where the longest "arms" in the plots represent the direction from which the wind is most common in that time period. August is the only month where the patterns are very consistent between each year, with winds coming mostly from the northeast. This would generally push waters into the inner bay, although modeling of the circulation shows more complex eddies and circulation patterns, shown subsequently. Winds in July vary somewhat between the years, however, they are general from the east, again likely to push waters towards the western and southwestern shore of the bay. The winds in September varied significantly between the three years.

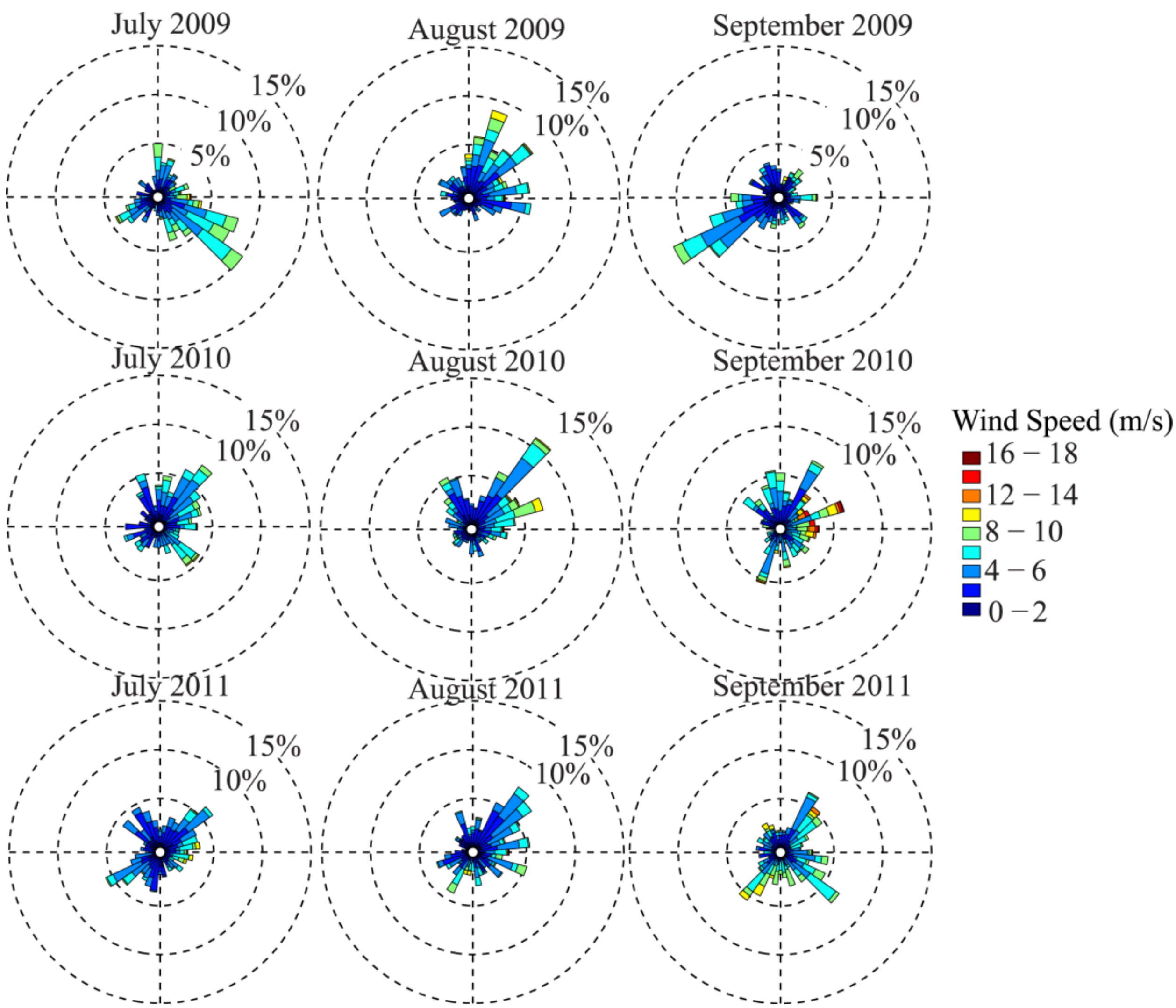


Figure 2.20: Monthly wind rose data for summer 2009-2011 in Saginaw Bay (Nguyen et al. 2014**).**

Nguyen et al. (2014) utilized a fine-scale unstructured grid model (different than the NOAA-GLERL forecasting model) to simulate the dominant circulation patterns in the bay for the three summer months (July, August, September) averaged over 2009-2011. The model shows (Figure

2.21) that all three months exhibit anti-cyclonic (i.e., clockwise rotating) gyre in each month in the outer bay. This is consistent with other studies that show the exchange with Lake Huron, where the gyre is cyclonic at the bay-lake interface. Circulation in the inner bay is more complex, with several different gyres moving waters in different directions. For both July and August, the circulation patterns are very similar, with outer bay water pushed into shore and splitting near the Saginaw River plume to flow along both the south eastern and western shores. Circulation in September shows much lower currents, as winds are generally more variable (Figure 2.20). The gyre in the inner bay for September shows a small cyclonic rotation near the mouth of the Saginaw River and currents may tend to follow the southeastern shore.

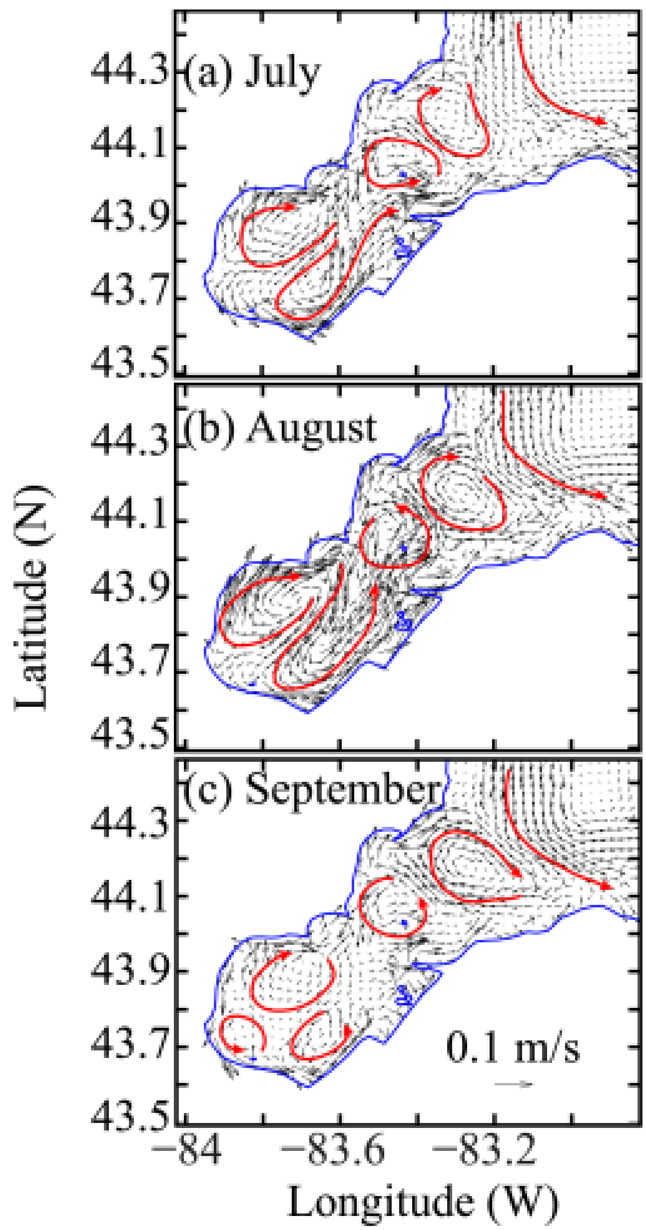


Figure 2.21. Average monthly circulation patterns from 2009-2011 in Saginaw Bay (Nguyen et al. 2014).

Integrated Assessment Implications and Summary

Agricultural controls in the Saginaw Bay watershed have long been investigated to reduce nutrient (primarily phosphorus) loads to the bay, with the assumption that several improvements in water quality would result. Reducing nutrients loads have been shown to result in reduced algal blooms and improved water clarity in many systems, however, the benefits of such reductions with regard to Cladophora may take many years to be realized. Sediments in the bay have stores of legacy nutrients that can stimulate algal growth, particularly benthic algae in close proximity to the nutrient flux from the sediments. Additionally, the role of dreissenids in prompting a shunt of nutrients to the sediments can also stimulate benthic algal growth. The SAGEM2 model demonstrates that even drastic reductions in external phosphorus loads will not result in complete elimination of Cladophora growth in the inner bay, although the peak growth at the mouth of the Saginaw River is reduced significantly.

The model also shows that increased water levels can play a role in the amount of Cladophora growth. Deeper waters limit the area that light can penetrate down to the sediments, and therefore remove some viable substrate are for benthic algae growth.

The model was also used to assess the relative contribution of the main tributaries to each model grid cell. This analysis demonstrated that while the Saginaw River provides approximately 82% of the TP load to the bay and dominates the overall nutrient balance, there are areas within the inner bay that are significantly influenced by other smaller tributaries.

While the SAGEM2 model is relatively fine-scale (1km horizontal grid cells) compared to many other water quality models, the size of the cells prohibits the model to be used to assess the impact of small scale piers, docks, or barrier nets which may be on the order of meters in size. However, the use of the NOAA-GLERL Saginaw Bay forecasting and nowcasting model can help give short term (48hr) predictions of the expected location of floating detritus near potential developments and beachfronts. The model is highly dependent on wind conditions, with dominant wind patterns generally demonstrating circulation patters in the recreational season that push water (and therefore muck) to the far western and eastern shores of the bay, separating around the Saginaw Bay plume in the inner bay.

References

Nguyen, T. D., P. Thupaki, E. J. Anderson and M. S. Phanikumar (2014) Summer circulation and exchange in the Saginaw Bay—Lake Huron System, *Journal of Gephysical Research of the Oceans* 119: 2713–2734.

Nevers, M.B., K. Przybyla-Kelly, A. Spoljaric, D. Shively, R.L. Whitman, and M.N Byappanahalli (2016) Freshwater wrack along Great Lakes coasts harbors Escherichia coli: Potential for bacterial transfer between watershed environments. *Journal of Great Lakes Research* 42: 760-767.

Russell, T. L., L. M. Sassoubre, C. Zhou, D. French-Owen, A. Hassaballah, and A. B. Boehm. (2014) Impacts of Beach Wrack Removal via Grooming on Surf Zone Water Quality. *Environmental Science and Technology* 48: 2203-2211.

Verhougstraete, M. P., and J. B. Rose (2014) Microbial investigations of water, sediment and algal mats in the mixed use watershed of Saginaw Bay, Michigan. *Journal of Great Lakes Research* 40(1): 75-82.

Appendix 2-A. Full bibliography of muck-related literature.

Badgley, B. D., J. Fergguson, Z. Hou, and M. J. Sadowsky. A model laboratory system to study the synergistic interaction and growth of environmental *Escherichia coli* with macrophytic green algae. 2012. *Journal of Great Lakes Research.* 38(2): 390-395.

Bierman Jr., V. J., and D. M. Dolan. Modeling of Phytoplankton in Saginaw Bay: 1. Calibration Phase. 1986. *Journal of Environmental Engineering.* 112(2): 400-414.

Bierman, V. J., J. Kaur, J. V. DePinto, T. J. Feist, and D. W. Dilks. Modeling the role of zebra mussels in the proliferation of blue-green algae in Saginaw Bay, Lake Huron. 2005. *Jurnal of Great Lakes Research.* 31(1): 32-55.

Bosch, I., J. C. Makeriwicz, T. W. Lewis, E. A. Bonk, M. Finiguerra, and B. Groveman. Management of agricultural practices results in declines of filamentous algae in the lake littoral. 2009. *Journal of Great Lakes Research.* 35(1): 90-98.

Bridgeman, T. B., G. L. Fahnenstiel, G. A. Lang, and T. F. Nalepa. Zooplankton grazing during the zebra mussel (*Dreissena polymorpha*) colonization of Saginaw Bay, Lake Huron. 1995. *Journal for Great Lakes Research.* 21(4): 567-573.

Budd, J. W., W. C.Kerfoot, and A. L. Maclean. Documenting complex surface temperature patterns from advanced very high resolution radiometer (AVHRR) imagery of Saginaw Bay, Lake Huron. 1998. *Journal of Great Lakes Research.* 24(3): 582-594.

Bykova, O., A. Laursen, V. Bostan, J. Bautista, and L. McCarthy. Do zebra mussels (*Dreissena polymorpha)* alter lake water chemistry in a way that favors *Microcystis* growth? 2006. *Science of the Total Environment.* 371(1-3): 362-372.

Cha, Y., and C. A. Stow. A Bayesian network incorporating observation error to predict phosphorus and chlorophyll *a* in Saginaw Bay. 2014. *Environmental Modeling & Software.* 57: 90-100.

Cha, Y., C. A. Stow, T. F. Nalepa, and K. H. Reckhow. Do invasive mussels restrict offshore phosphorus transport in Lake Huron? 2011. *Environmental Science & Technology.* 45(17): 7226-7231.

Chakraborti, R. K., J. Kaur, and J. V. DePinto. Analysis of Factors Affecting Zebra Mussel (*Dreissens polymorpha*) Growth in Saginaw Bay: A GIS-Based Modeling Approach. 2002. *Journal of Great Lakes Research*. 28(3): 396-410.

Cooper, M. J., G. A. Lamberti, and D. G. Uzarski. Spatial and temporal trends in invertebrate communities of Great Lakes coastal wetlands, with emphasis on Saginaw Bay of Lake Huron. 2014. *Journal of Great Lakes Research.* 40(1): 168-182.

Dyble, J. G. L. Fahnenstiel, R. W., D. F. Millie, and P. A. Tester. Microcystin concentrations and genetic diversity of Microcystis in the lower Great Lakes. 2008. *Environmental Toxicology.* 23(4): 506-518.

Edwards, W.J., C. R. Rehmann, E. McDonald, and D. A. Culver. The impact of a benthic filter feeder: limitations imposed by physical transport of algae to benthos. 2005. *Canadian Journal of Fisheries and Aquatic Sciences.* 62(1): 205-214.

Fahnenstiel, G. L., T. B. Bridgeman, G. A. Lang, M. J. McCormick, and T. F. Nalepa. Phytoplankton productivity in Saginaw Bay, Lake Huron: Effects of zebra mussel (*Dreissens polymorpha*) colonization. 1995. *Journal of Great Lakes Science*. 21(4): 465-475.

Fahnenstiel, G. L., D. F. Millie, J. Dyble, R. W. Litaker, P. A. Tester, M. J. McCormick, R. Rediske, and D. Klarer. *Microcystin* concentrations and cell quotas in Saginaw Bay, Lake Huron. 2008. *Aquatic Ecosystem & Health Management.* 11(2): 190-195.

Fishman, D. B., S. A. Adlerstein, H. A. Vanderploeg, G. L. Fahnenstein, and D. Scavia. Causes of phytoplankton changes in Saginaw Bay, Lake Huron, during the zebra mussel invasion. 2009. *Journal of Great Lakes Research*. 35(4): 482-495.

Fishman, D. B., S. A. Adlerstein, H. A. Vanderploeg, G. L. Fahnenstein, and D. Scavia. Phytoplankton community composition of Saginaw Bay, Lake Huron, during the zebra mussel (*Dreissena polymorpha*) invasion: a multivariate analysis. 2010. *Journal of Great Lakes Research*. 36(1): 9-19.

Francoeur S. N., K. P. Winslow, D. Miller, C. A. Stow, Y. Cha, and S. D. Peacor. Spatial and temporal patterns of macroscopic benthic primary producers in Saginaw bay, Lake Huron. 2014. *Journal of Great Lakes Research.* 40(1): 53-63.

Gergs, R., K. Rinke, and K. O. Rothhaupt. Zebra mussels mediate benthic-pelagic coupling by biodeposition and changing detrital stoichiometry. 2009. *Freshwater Biology.* 54(7): 1379-1391.

Hawley, N., T. Redder, R. Beletsky, E. Verhamme, and J. V. DePinto. 2014. Sediment re-suspension in Saginaw Bay. *Journal of Great Lakes Research.* 40(1): 18-17.

He C. S., L. H. Zhang, C. DeMarchi, and T.E. Croley. Estimating point and non-point source nutrient loads in the Saginaw Bay watersheds. 2014. *Journal of Great Lakes Research*. 40(1): 11-17.

Heath, R. T., G. L. Fahnenstiel, W. S. Gardner, J. F. Cavaletto, and S. J. Hwang. Ecosystem-level effects of zebra mussels (*Dreissena polymorpha*): An enclosure experiment in Saginaw Bay, Lake Huron. 1995. *Journal of Great Lakes Research*. 21(4):501-516.

Laryentev, P. J., W. S. Gardner, J. F. Cavalett, and J. R. Beaver. Effects of zebra mussel (*Dreissena polymorpha Pallas*) on protozoa and phytoplankton from Saginaw Bay, Lake Huron. 1995. *Journal of Great Lakes Research.* 21(4): 545-557.

Lavrentyev, P. J., H. A. Vanderploeg, G. Franzé, D. H. Chacin, J. R. Liebig, and T. H. Johengen. Microzooplankton distribution, dynamics and trophic interaction relative to phytoplankton and quagga mussels in Saginaw Bay, Lake Huron. 2014. *Journal of Great Lakes Research.* 40(1): 95-105.

Lehman, J. T., A. Bazzi, T. Nosher, and J. O. Nriagu. Copper inhibition of phytoplankton in Saginaw Bay, Lake Huron. 2004. *Canadian Journal of Fisheries and Aquatic Sciences.* 61(10): 1871-1880.

Lowe, R. L., and R. W. Pillsbury. Shifts in benthic algal community structure and function following the appearance of zebra mussel (*Dreissena polymorpha*) in Saginaw Bay, Lake Huron. 1995. *Journal of Great Lakes Research.* 21(4): 558-566.

Millie, D. F., G. L. Fahnenstiel, G. R. Weckman, D. M. Klarer, J. Dyble, H. A. Vanderploeg, and D. B. Fishman. An "enviro-informatic" assessment of Saginaw Bay (Lake Huron, USA) phytoplankton: data-driven characterization and modeling of *Microcystis* (cyanophyta). 2011. *Journal of Phycology*. 47(4): 714-730.

Millie, D. F., G. L. Fahnenstiel, J. Dyble, R. Pigg, R. Rediske, D. M. Klarer, R. W. Litaker, and P. A. Tester. Influence of environmental conditions on late-summer cyanobacterial abundance in Saginaw Bay, Lake Huron. 2008. *Aquatic Ecosystem & Health Management.* 11(2): 196-205.

Millie, D. F., G. R. Weckman, R. J. Pigg, P. A. Tester, J. Dyble, R. W. Litaker, H. J. Carrick, and G. L. Fahnenstiel. Modeling phytoplankton abundance in Saginaw Bay, Lake Huron: Using artificial neural networks to discern functional influence of environmental variables and relevance to a great lakes observing system. 2006. *Journal of Phycology.* 42(2): 336-349.

Naddafi, R., K. Pettersson, and P. Eklov. 2008. Effects of zebra mussel, and exotic freshwater species, on seston stoichiometry. *Limnology and Oceanography.* 53(5): 1973-1987.

Nalepa, T. F., G. L. Fahnenstiel, and T. H. Johengen. Impacts of zebra mussel (*Dreissens polymorpha*) on water quality: A case study in Saginaw Bay, Lake Huron. 2000. *Nonindigenous Freshwater Organisms.* 255-271.

Nalepa, T. F., D. L. Fanslow, M. B. Lansing, and G. A. Lang. Trends in the Benthic Macroinvertabrate Community of Saginaw Bay, Lake Huron, 1987 to 1996: Responses to Phosphorus Abatement and the Zebra Mussel, *Dreissena polymorpha*. 2003. *Journal of Great Lakes Research.* 29(1): 14-33.

Nguyen, T. D., P. Thupaki, E. J. Anderson, and M. S. Phanikumar. Summer circulation and exchange in the Saginaw Bay-Lake Huron system. 2014. *Journal of Geophysical Research: Oceans.* 119(4): 2713-2734.

Pillsbury, R. W., R. L. Lowe, Y. D. Pan, and J. L. Greenwood. Changes in the benthic algal community and nutrient limitation in Saginaw Bay, Lake Huron, during the invasion of the zebra mussel (*Dreissena polymorpha*). 2002. *Journal of the North American Benthological Society.* 21(2): 238-252.

Russell, T. L., L. M. Sassoubre, C. Zhou, D. French-Owen, A. Hassaballah, and A. B. Boehm. (2014) Impacts of Beach Wrack Removal via Grooming on Surf Zone Water Quality. *Environmental Science and Technology* 48: 2203-2211.

Sarnelle, O., A. E. Wilson, S. K. Hamilton, L. B. Knoll, and D. F. Raikow. Complex interactions between the zebra mussel, *Dreissena polymorpha*, and the harmful phytoplankton, *Microcystis aeruginosa.* 2005. *Limnology and Oceanography.* 50(3): 896-904.

Seltzer, M. D., B. Joldersma, and J. Beard. A reflection on restoration progress in the Saginaw Bay watershed. 2014. *The Journal of Great Lakes Research.* 40(1): 192-200.

Siersma, H. M. H., C. J. Foley, C. J. Nowicki, S. S. Qian, and D. R. Kashian. Trends in the distribution and abundance of *Hexigenia spp.* in Saginaw Bay, Lake Huron, 1954-2012: Moving towards recovery? *Journal of Great Lakes Research*. 40(1): 156-167.

Stow, C. A., and Y. Cha. Are chlorophyll a-total phosphorus correlations useful for inference and prediction? 2013. *Environmental Science & Technology.* 47(8): 3768-3773.

Stow, C. A., J. Dyble, D. R. Kashian, T. H. Johengen, K. P. Winslow, S. D. Peacor, S. N. Francoeur, A. M. Burtner, D. Palladino, N. Morehead, D. Gossiaux, Y. K. Cha, S. S. Qian, and D. Miller. 2014. Phosphorus targets and eutrophication objectives in Saginaw Bay: A 35 year assessment. *Journal of Great Lakes Research*. 40(1): 4-10.

Stanley, K. E., P. G. Murphy, H. H. Prince, and T. M. Burton. Long-Term Ecological Consequences of Anthropogenic Disturbance on Saginaw Bay Coastal Wet Meadow Vegetation. 2005. *Journal of Great Lakes Research.* 31(1): 147-159.

Tang, H., H. A. Vanderploeg, T. H. Johengen, and J. R. Liebig. Quagga mussel (*Dreissena rostriformis bugensis*) selective feeding of phytoplankton in Saginaw Bay. 2014. *Journal of Great Lakes Research*. 40(1): 83-94.

Turner C. B. Influence of Zebra (*Dreissena polymorpha*) and quagga (*Dreissena rostriformis*) mussel invasions on benthic nutrient and oxygen dynamics. 2010. *Canadian Journal of Fisheries and Aquatic Sciences.* 67(12): 1899-1908.

Verhougstraete, M. P., and J. B. Rose. Microbial investigations of water, sediment and algal mats in the mixed use watershed of Saginaw Bay, Michigan. 2014. *Journal of Great Lakes Research.* 40(1): 75-82

Vanderploeg, H. A., J. R. Liebig, W. W. Carmichael, M. A. Agy, T. H. Johengen, G. L. Fahnenstiel, and T. F. Nalepa. Zebra mussel (*Dreissena polymorpha*) selective filtration promoted toxic *Microcystis* blooms in Saginaw Bay (Lake Huron) and Lake Erie. 2001. *Canadian Journal of Fisheries*. 58(6): 1208-1221.

Vanderploeg, H. A., T. H. Johengen, and J. R. Liebig. Feedback between zebra mussel selective feeding and algal composition affects mussel condition: did the regime changer pay a price for its success? 2009. *Freshwater Biology.* 54(1): 47-63.

Vanderploeg, H. A., J. R. Liebig, and M. Omair. Bythotrphes predation on Great-Lakes zooplankton measured by an in situ method - implications for zooplankton community structure. 1993. *Archiv Fur Hydrobiologie.* 127(1): 1-8.

Voss, H. M., M. E. VanWert, J.R. Polega, J. W. VanHouten, A. L. Martin, and D. S. Karpovich. 2014. Implications of hypoxia on the north branch of the Kawkawlin River. *Journal of Great Lakes Research.* 40(1): 28-34.

Watson, S. B., J. Ridal, and G. L. Boyer. Taste and odour and cyanobacterial toxins: impairment, prediction and management in the Great Lakes. 2008. *Canadian Journal of Fisheries and Exotic Sciences.* 65(8): 1779-1796.

White, J. D., R. B. Kaul, L. B. Knoll, A. E. Wilson, and O. Sarnelle. Large variation to grazing within a population of the colonial phytoplankter, *Microcystis aeruginosa.* 2011. *Limnology and Oceanography*. 56(5): 1714-1724.

Winslow, K. P., S. N. Francoeur, and S. D. Peacor. The influence of light and nutrients on benthic filamentous algal growth: A case study of Saginaw Bay. 2014. *Journal of Great Lakes Research.* 40(1): 64-74.

Yu-Chun, Kao, S. Adlerstein, and E. Rutherford. 2014. The relative impacts of nutrient loads and invasive species on a Great Lakes food web: An Ecopath and Ecosim analysis. *Journal of great lakes research.* 40(1): 35-42.

Chapter 3: Economic impacts of current and future water and beach quality at BCSRA[1]

Problematic algal blooms are a severe issue affecting the Great Lakes. This problem occurs when large mats of filamentous green algae (e.g., *clodophera*) break apart and form unsightly mats or even "muck" that fouls beaches (Natural Resources Defense Council, 2009; Verhougstraete et al., 2010). There are emerging economic incentives that may drive public and policy makers to improve the water quality. Traditionally, the Great Lakes have been used for municipal and industrial water supply, commercial fishing, and transportation, and although all these uses propelled the Michigan economy, some of them have the potential to degrade water quality. Recently state and local governments are becoming increasingly interested in the "Growing Michigan's Blue Economy" Initiative (Austin & Steinman, 2015), which proposes to develop water-related industries in a clean, healthy, and sustainable way. In light of this possible transition, water quality improvement is crucial for the success of the initiative and the development of "blue" industries. In particular, as beach recreation has always played an important role in outdoor recreation, water quality improvements can directly benefit beach recreation and then contribute to local economies.

Accordingly, to prevent further degradation of water quality or to improve existing water quality of the Great Lakes will require resources. Because there are only limited funds for competing uses of many natural resources, information on the benefits of water quality protection or improvement are vital in policy makers' efforts to allocate funds and justify funding decisions. Furthermore, inaccurate estimates can undermine the credibility of water quality improvement programs and may cause their untimely failure (EPA, 1989), which emphasizes the need for quality information.

Although decision makers have an increasing demand on the information, measuring water quality improvements in terms of economic benefits and economic impacts is still challenging. The first challenge lies in the complexity of identifying benefits from water quality improvements (Keeler et al, 2012). Because water quality improvements affect many aspects of human well-being, returns can accrue to recreational use, human health, and commercial use. Failing to consider all the returns will underestimate the benefits. However, as Bockstael, Hanemann and

[1] The economic analyses of this chapter were coauthored with Li Cheng and draw from Cheng and Lupi (2016a, 2016b, 2016c) as well as the introductory chapter of Cheng (2016).

Kling (1987) indicated significant benefits from surface water quality improvements accrue to recreational use, yet little is known about these impacts in the Great Lakes. Thus, we consider recreational beach use, mainly because the Michigan Activity Survey (conducted by Lupi and colleagues) found that visiting a beach is more popular than fishing or boating on the Great Lakes.

The second critical challenge lies in the complexity of defining water quality metrics. Water quality is sometimes measured on scales based on a combination of many chemical and biophysical variables in a small sample of water, but it is often difficult to describe overall water quality status in a large waterbody from a large number of variables (Griffiths et al, 2012). Besides, these chemical and biophysical measures may not be directly related to the water quality attributes that people actually perceive and value (Kneese 1968; Keeler et al, 2012). To address this challenge, we utilized water quality attributes that were described by their visual impact and were used in a choice experiment that was further combined with trip data to infer the recreation benefits of water quality improvements from observed behaviors and stated preferences. The water quality attributes were designed to be policy-relevant since they match those that EPA collects through its beach sanitation survey monitoring program (EPA 2008).

The third challenge lies in the lack of substitution effects in recreation demand from water quality changes in most economic impact studies. As Deisenroth, Loomis and Bond (2013) pointed out, most economic impact studies only provide a “snapshot” of an activity’s contribution at a given point in time. However, the economic impacts from water quality changes involve changes of economic demand. In particular, when water quality decreases, human behavior responds and people can choose to visit different sites or to forego visiting at all. Thus, quantifying economic impacts from water quality changes cannot simply rely on a “snapshots” of trips, because failure to account for substitution effects in recreational demand from water quality change results in overestimation of economic impacts (Deisenroth, Loomis & Bond, 2013).

What are *economic impacts* and *economic values*? This report presents information on two very distinct economic concepts that relate to the quality of beaches and beach visitation: (1) economic values to beach visitors and (2) beach-related spending and the associated *economic impacts* for the economy. *Economic impacts* of beach visitor spending measure changes in regional economic activity such as economic output (e.g., sales), incomes, and jobs (Watson et al., 2007). *Economic values* to beachgoers measure changes in visitors’ economic well-being net of their costs (Freeman et al. 2014). Put differently, the latter is the economic benefit to beachgoers of their visitation. Notably, the two types of economic metrics are not typically directly comparable. For example, from the perspective of a beach visitor, the money they spend to visit the beach (e.g., fuel expenditures) represents a *cost* to them. Their spending (i.e., their cost) is not their benefit. Their benefit, as measured in economics, is the difference between what they would be willing to pay to visit the beach and what they have to pay (their cost). This difference is referred to as their consumer surplus or their welfare gain. For a visitor, all else equal, higher costs make them worse off. Never the less, for the economy, the spending from beach visitors contributes to the amount of economic activity in a region. Both of these metrics can be useful for decision making, but care must be taken in their application (Watson et al. 2007).

The objective of this chapter is to conduct economic analyses related to beach visitation and a BCSRA impact survey to understand how recreational values and park management are impacted by muck conditions. These objectives fall within a larger study that measured the monetary value of public Great Lakes beaches, measured the monetary value of water quality improvements to Great Lakes beaches, estimated the trip expenditures of recreational beachgoers to Great Lakes beaches, and finally, estimated the economic impacts of beach recreation and the economic impacts of water quality improvements by establishing the critical linkages between water quality and beach recreation. This study includes all regions of the state, and focuses on several beaches in particular, but this chapter will focus on findings specific to Saginaw Bay beaches.

The chapter is organized as follows: Section 1 presents the underlying behavioral model of beach site visitation demand that links beach uses to measures of algae on beaches and in the water; section 2 presents the data collection and estimation of a beach spending model used to impute beach spending so it can be coupled with the model of section 1; and section 3 presents the coupled model linking changes in beach spending to levels of algae.

1. Combining Revealed and Stated Preference Methods for Valuing Water Quality Changes to Great Lakes Beaches in Michigan[2]

Water quality of the Great Lakes is highly valued by policy makers and the public. Many legislative efforts and government regulations, such as Clean Water Act (CWA, 1970, 1972) and

[2] This section draws from Cheng and Lupi (2016a) and Essay 2 of Cheng (2016), which contain the complete methods details, all demand and valuation equations, econometric specifications and estimation results.

Great Lakes Water Quality Agreement (GLWQA, 1972, 1978, 1987, 2012), have been enacted to restore and enhance the water quality of the Great Lakes over the last decades. Public policies toward water quality can benefit from information about the economic benefits of improvement or protection of water quality. Although valuing water quality changes is particularly challenging as compared to other environmental services (Keeler et al. 2012), we can estimate some of the monetary value of water quality improvements by measuring the recreational benefit of water quality improvement, as one of the major benefits from improving water quality accrues to recreational use (Bockstael, Hanemann, & Kling, 1987).

Two primary approaches have been applied to the measurement of recreational benefits: revealed preference (RP) approaches and stated preference (SP) approaches. RP approaches, such as the "travel cost method", rely on observed behaviors to indirectly derive values of environmental services. By contrast, SP approaches, such as "choice experiments" or the "contingent valuation method", ask the individual to make hypothetical choices to directly elicit values.

Both RP and SP approaches have advantages and disadvantages, and each approach faces challenges in valuing water quality changes. For RP approaches, challenges in valuing the water quality changes mainly lie in three aspects. First, unlike air quality, which has a comparatively small number of accepted measures of quality, water quality is scaled by a large number of chemical and biophysical variables. Evaluating overall water quality status from a large number of variables is often difficult (Kannel et al. 2007). Second, understanding the link between the biophysical characteristics and the recreational attributes of water quality has long been, and continues to be a challenge for selecting the appropriate variables to describe water quality (Kneese & Bower, 1968; Keeler et. al, 2012). Third, among the few studies conducted on valuing water quality by using biophysical attributes, they either require a considerably rich dataset (Egan et al. 2009), or they often suffer from problems of multicollinearity (see Bockstael, Hanemann, & Kling, 1987 for a discussion) or missing attribute levels, as suggested by Adamowicz et al. (1997). On the other hand, although SP approaches can readily address subjective measures of water quality changes, SP approaches have been criticized for being hypothetical because their estimates are based on respondents' *ex ante* choices.

The purpose of this study is to estimate the values of water quality changes for beach recreation in the Great Lakes. By using data from the web survey of 2,537 Michigan beachgoers (Cheng and

Lupi, 2016), this section builds on the Chen (2013), an earlier SP study by Weicksel (2012). The web survey consists of two types of data: one is revealed preference data, which is collected by asking about respondents' trips to public beaches at the Great Lakes in Michigan; and the other is stated preference data, which involves asking respondents in a choice experiment to choose from hypothetical choice sets in which the beaches were constructed with different environmental quality attributes.

Survey and Data

Survey

The data used for this study are drawn from the Great Lakes Beaches Survey[3], which was conducted by Lupi, Kaplowitz, Chen and Weicksel in 2011 and 2012. First, in order to recruit beachgoers, a mail survey on leisure activities was conducted with the general population of Michigan residents. A random sample of 32,230 was drawn from the Michigan driver's license list. To reduce potential self-selection bias that might over-select for those that visit the Great Lakes, the mail survey has numerous questions on a broad range of indoor and outdoor leisure activities, among which there was only one screening question for Great Lakes beach recreation during two summers in 2010 and 2011. Respondents who answered they had participated in beach recreation were counted as beachgoers and were subsequently invited to take a follow-up web survey.

There are three sections in the follow-up web survey: a travel cost section, which collected trip information about respondents' trips to public Great Lakes beaches in one summer season from Memorial Day weekend to September 30, 2011; a choice experiment section, which gathered respondents' preferred beach in each of three different choice sets with experimentally designed attributes; and finally, a section of demographic questions.

Data

In the mail survey dataset of 9,591 observations, 5,737 respondents indicated they had visited a Great lakes beach in 2010 or 2011, so they were invited to the web survey. There were 3,196 people who responded to the web survey resulting in a response rate for the web survey of about

[3] See Chen (2013), Weicksel (2012) for additional details regarding the survey sampling and implementation.

59%. Chen (2013) made use of all trip data to estimate the value of trips to Great Lakes beaches by applying a nested logit model. Among the 2,573 observations, 1,894 individuals took at least one trip to Great Lakes beaches during the beach season. The trip data consists of self- reported trips to Great Lakes beaches from Memorial Day weekend to September 30, 2011. After matching the reported beaches to the Michigan DEQ beach database, the choice set for each individual is comprised of 451 beaches. There are 643 people who had taken trips to Great Lakes beaches before but didn't take any trip during the indicated season, they are treated as potential users and also included in this study.

SP surveys included questions related to water quality attributes and how visitation would change. Table 3.1 lists the water quality attributes and attribute levels for the SP model (travel costs and beach length are not show in the table).

Table 3.1 Explanations of attributes and attribute levels in sp data

Attributes	Attribute Levels
Label: Great Lakes name	Lake Michigan Lake Huron Lake St. Clair Lake Erie
Algae in the water	None Low (rarely come in contact with algae) Moderate (sometimes come in contact with algae) High (constantly come in contact with algae)
Algae on the shore	None Low (1-20% of the shore has algae) Moderate (21-50% of the shore has algae) High (more than 50% of the shore has algae)
Testing water for bacteria	Never Monthly Weekly Daily

Results

Results indicate that Michigan beachgoers prefer less algae in the water and less algae on the shore. Furthermore, magnitudes of estimated parameters of algae levels in the water are higher than those of algae levels on the shore, which reveals that beachgoers have a stronger dislike of algae in the water than on the shore. Regarding the frequency of testing water for bacteria, beachgoers prefer water tested daily to water tested weekly or never tested at all. All else equal, beachgoers favor Lake Michigan the most, followed by Lake Huron. All the above results are similar to those found in Weicksel (2012).

To understand how visitation varied by different environmental quality attributes, surveyors went to sites and categorized the algae level in the water and on the shore to three levels: low, medium and high. There are 1,955 observations from Great Lakes Beach Sanitary Survey for 128 beaches in our choice set, of which 74 beaches have the information for algae levels in the water and 66 beaches have the information for algae levels on the shore. When we aggregated the water quality information at the regional level, information for the Northeast region is missing, so we assume the water quality in the Northeast is same as the Northwest. In the sanitary survey data testing for bacteria rarely happened since it is reported elsewhere. Therefore, the attribute of testing for bacteria is no longer included in water quality scenarios we examine here. Water quality is thus defined by algae level in the water and algae level on the shore as *low, medium,* or *high.* In our policy scenarios, when we refer to water quality change, we mean the algae level in the water and the algae level on the shore are simultaneously changed in the same direction.

Tables 3.2 and 3.3 provide the baseline distribution of water quality across regions. The tables show that water quality in the LP Mid-East region and LP Southeast region is much lower than the water quality of the other regions based on the amounts of algae present.

Table 3.2 The baseline distribution of algae level in the water across region in 2011. Saginaw Bay is considered LP Mid-East region (bold).

	Low	Medium	High
LP Northeast	81.18%	18.04%	0.78%
LP Mid-East	52.43%	20.39%	27.18%
LP Southeast	57.79%	18.85%	23.36%
LP Northwest	81.18%	18.04%	0.78%
LP Mid-West	95.65%	2.17%	2.17%
LP Southwest	100.00%	0.00%	0.00%
Upper Peninsula	91.30%	6.52%	2.17%

Table 3.3 The baseline distribution of algae level on the shore across region in 2011. Saginaw Bay is considered LP Mid-East region.

	Low	Medium	High
LP Northeast	86.99%	12.20%	0.81%
LP Mid-East	59.48%	20.69%	19.83%
LP Southeast	75.33%	22.91%	23.79%
LP Northwest	86.99%	12.20%	0.81%
LP Mid-West	100.00%	0.00%	0.00%
LP Southwest	100.00%	0.00%	0.00%
Upper Peninsula	94.05%	4.76%	1.19%

We consider two types of scenarios. The first scenario assumes that water quality at half of the sites in a region is improved *up* by one level. Simply put, half of Great Lakes beaches in a region with the high algae level are improved to the medium level and half of beaches in a region with the medium algae level are improved to the low level. Take Northeast region as an example, under the first scenario, high algae level in the water/on the shore becomes half of the baseline value of the low level, which means that 0.39% of Great Lakes beaches in the Northeast maintain a high algae level in the water and 0.4% of beaches maintain a high algae level on the shore. Medium algae level in the water/on the shore turns out to be half of the sum of baseline values of the low level and the medium level, which means 9.41% of beaches in the Northeast attain a medium algae level in the water and 6.51% of beaches attain a medium algae level on the shore. Finally, 90.2% of Great Lakes beaches in the Northeast attain a low algae level in the water and 93.09% of beaches attain a low algae level on the shore. The same procedures are applied to the water quality of the other five regions under the first scenario.

The second scenario assumes that water quality is deteriorated by shifting half of the sites' water quality in a region *down* by one level. This is a significant change in water quality, because half of beaches with the low algae level are degraded to the medium level and half of beaches with the medium algae level are degraded to the high level. The distribution of algae levels moves in the opposite direction to the algae levels in the first scenario. In both types of scenarios the algae changes are made only within one region at a time, resulting in twelve total welfare scenarios (an improvement and decrement to quality in each of six regions). Measure of welfare is defined as the beachgoer's willingness to pay to visit a beach minus their cost of doing so.

Table 3.4 displays the predicted trips and welfare estimates from the first scenario of water quality improvement. If we improve half of Great Lakes beaches' water quality in a region *up* by one level, compared to the trips taken at status quo, the trips increases by 33.62% for Middle-East region (Huron South) and 20.49% for Southeast region (St. Clair and Erie). Trips increase slightly for Huron North and Lake Michigan. The intuition behind this is that the baseline algae levels in Huron South, St. Clair, and Erie are higher than those in Huron North and Lake Michigan. Once we increase the water quality, the utility of a person is increasing as the algae level decreases. Therefore, improving water quality leads to more utility increase for beaches with initially higher algae level in Huron South, St. Clair, and Erie than beaches with initially lower algae level in Huron North and Lake Michigan.

Under the water quality improvement scenario, the seasonal welfare benefits to beachgoers are larger for Huron South, St. Clair, and Erie as well. St. Clair and Erie generate the largest seasonal welfare gains, with $9.92 in seasonal value obtained for an average Michigan beachgoer. When normalized by the site trip change, the seasonal value per person per trip is $50.73. Although Huron South has the second highest seasonal value per person at $4.9, it has a relatively small number of trips, so the seasonal value per person per trip turns out to be the second lowest at $33.36 when normalizing by the site trip change. Seasonal value is defined as the total consumer surplus changes across the season represented by the model (i.e., Memorial Day weekend through September).

By contrast, if we degrade half of Great Lakes beaches' water quality in a region *down* one level, trips decrease dramatically and welfare loss turns out to be significant. Table 3.5 displays the predicted trips and welfare estimates from the second scenario of the water quality deterioration. Compared to the trips taken at status quo, all regions lose trips and the magnitude of decreased trips ranges from 24.09% to 32.66% across the six regions. When aggregated at the state level, 1.76 million trips are lost in the Northwest region due to degrading half of Great Lakes beaches' water quality *down* by one level. Mid-west region loses 1.75 million trips, followed by Southwest region losing 1.04 million trips. Mid-East region loses 0.6 million trips, which is the least trip loss among the six regions. The range of trip loss indicates that the water quality degradation impacts Lake Michigan most and Huron south least. When aggregated at the state level, South Huron incurs the least welfare losses at $18.96 million.

Table 3.4 Estimated trips and welfare measures of shifting half of sites' water quality up by one level in a region in 2011 dollars. Saginaw Bay is considered LP Mid-East region (bold).

		Number of Trips	Number of Site Trips Change	% Changes in Trips	Seasonal Value	Season/Total Trip Change	Season/Site Trip Change
Take Half of Sites' Algae in the Water & Algae on the Shore *up* by one Level	LP Northeast	0.68	0.03	4.96%	1.21	92.34	37.77
	LP Mid-East	**0.58**	**0.15**	**33.62%**	**4.90**	**90.79**	**33.36**
	LP Southeast	1.15	0.20	20.49%	9.92	89.98	50.73
	LP Northwest	1.62	0.06	4.05%	2.91	94.54	46.07
	LP Mid-West	1.74	0.02	1.21%	0.88	92.74	42.40
	LP Southwest	0.97	0.00	0.00%	0.00	0.00	0.00

State level

		Number of Trips (Million)	Number of Site Trips Change (Million)	% Changes in Trips (Million)	Seasonal Value (Million)
Take Half of Sites' Algae in the Water & Algae on the Shore up by one Level	LP Northeast	2.872	0.136	4.96%	5.122
	LP Mid-East	**2.468**	**0.621**	**33.62%**	**20.717**
	LP Southeast	4.862	0.827	20.49%	41.937
	LP Northwest	6.857	0.267	4.05%	12.283
	LP Mid-West	7.357	0.088	1.21%	3.719
	LP Southwest	4.111	0.000	0.00%	0.000

Note: The table rows are for the 12 regional scenarios each run separately. Only changes within a region are shown and site substitution patterns for each scenario are omitted for brevity.

Table 3.5 Estimated trips and welfare measures of shifting half of sites' water quality *down* by one level in a region in 2011 dollars. Saginaw Bay is considered LP Mid-East region (bold).

Per Person

		Number of Trips	Number of Site Trips Change	% Changes in Trips	Seasonal Value	Season/Total Trip Change	Season/Site Trip Change
Take Half of Sites' Algae in the Water & Algae on the Shore *down* by one Level	LP Northeast	0.44	-0.21	-32.14%	-7.57	92.25	36.37
	LP Mid-East	**0.29**	**-0.14**	**-32.66%**	**-4.49**	**90.68**	**31.44**
	LP Southeast	0.72	-0.24	-24.58%	-11.36	89.74	48.41
	LP Northwest	1.14	-0.42	-26.74%	-18.86	94.26	45.26
	LP Mid-West	1.31	-0.41	-24.09%	-16.81	92.56	40.58
	LP Southwest	0.73	-0.25	-25.28%	-9.24	92.02	37.58

State level

		Number of Trips (Million)	Number of Site Trips Change (Million)	% Changes in Trips (Million)	Seasonal Value (Million)
Take Half of Sites' Algae in the Water & Algae on the Shore *down* by one Level	LP Northeast	1.857	-0.880	-32.14%	-31.986
	LP Mid-East	**1.244**	**-0.603**	**-32.66%**	**-18.963**
	LP Southeast	3.044	-0.992	-24.58%	-48.015
	LP Northwest	4.828	-1.763	-26.74%	-79.766
	LP Mid-West	5.518	-1.751	-24.09%	-71.076
	LP Southwest	3.071	-1.039	-25.28%	-39.050

Note: The table rows are for the 12 regional scenarios each run separately. Only changes within a region are shown and site substitution patterns for each scenario are omitted for brevity

Conclusion and Discussion (Section 1)

This section investigated combining revealed and stated preference data to jointly estimate the monetary value of water quality attributes and their economic benefits to recreational beachgoers. Results indicate that Michigan beachgoers prefer less algae in the water and less algae on the shore. Furthermore, magnitudes of estimated parameters of algae levels in the water are higher than those of algae levels on the shore, which reveals that beachgoers have a stronger dislike of algae in the water than on the shore.

We then applied the calibration of SP to RP approach to measure the change in consumer surplus (economic value to the beachgoers) in response to two types of hypothetical water quality scenarios. If we improve half of Great Lakes beaches' water quality in a region *up* by one level, compared to the trips taken at status quo, trips increase by 33.62% and seasonal welfare value increases by $20.717 million for Mid-East region (Huron South). Therefore, improving water quality leads to more utility increase for beaches with initially higher algae level. If we degrade half of Great Lakes beaches' water quality in a region *down* one level, compared to the trips taken at status quo, each region loses trips so dramatically that the magnitude of decreased trips ranging from 24.09% to 32.66% across the six regions. The South Huron (Saginaw Bay region) scenario incurs the largest decrease in trips (-32.66% change) and a season value loss of $18.96 million.

2. Estimating Spending for Trips to Great Lakes Beaches in Michigan[4]

Michigan has over 500 beaches on the shoreline of the Great Lakes. Each year millions of visitors from all over the state visit Great Lakes beaches. During their visits, they may spend money on transportation, food, beverages, and lodging. This spending will contribute to local economic

---

[4] This section draws from Cheng and Lupi (2016b) and Essay 3 of Cheng (2016), which contain the complete methods details, the spending equations, econometric specifications and estimation results.

development because the recreation demand induces consumption at local gas stations, grocery stores, restaurants, and hotels.

Despite their popularity among Michigan residents' recreational activities, Great Lakes beaches face threats from a combination of factors that include bacterial contaminants, invasive species, algal growth, harmful algae blooms, shoreline development and land uses, and climate change. All of these threats pose challenges for beach recreation. Quantifying the contribution of beaches to the local economy can inform policy makers of the some of the importance of preserving and restoring beaches. Because there are limited funds for competing uses of many natural resources, policy makers need to evaluate preservation and restoration programs to justify funding decisions. Policy makers evaluating beach programs not only need to consider the costs and benefits but also the distributional implications of the program. Understanding the regional distribution of the recreational activity, however, requires measurement of the locations and economic impacts.

Visitor spending is an essential component of economic impact analysis. An economic impact analysis focused on beach recreation can help policy makers, more specifically, park and recreation administrators and planners, as well as the local community, evaluate potential beach development or protection programs. By using data on beachgoers' from a web survey, Chen (2013) was the first to apply a recreation demand model to value Great Lakes beaches. Cheng and Lupi (2016) extended Chen's (2013) study by using both day trips and overnight trips data to value the Great Lakes beaches. In this study, we use the demand system based on Cheng and Lupi (2016) to predict the regional variation of trips to Great Lake beaches. The objectives for this chapter is to estimate regional variation of spending per trip per person to Great Lakes beaches in Michigan during a beach season.

Methods

Two surveys are applied in this section. The first one is the Great Lakes Beaches Survey, which is used for the purpose of trip prediction. The second survey is the Beach visitor spending survey, which is used for the spending estimation.

Great Lakes Beaches Survey is a two-stage survey developed by Lupi, Kaplowitz, Chen, and Weicksel in 2011 as described in detail in Cheng and Lupi (2016) (see also Chen 2013 and Weicksel 2012). In this section, we use the trip prediction based on the demand systems in Cheng and Lupi (2016) and the demographic information from the Great Lakes beaches survey.

The Beach Visitor Spending Survey first involves on-site recruitment of subjects by intercepting beachgoers and distributing an invitation letter with a unique web address to access a web-based survey. The recruitment of subjects took place in three public beaches in Michigan in the summer of 2014, specifically, the Bay City Recreation State Park (Lake Huron), the Grand Haven State Park (Lake Michigan), and the Metropolitan Beach Metro Park (Lake St. Clair). The interviewer would ask for the individual's zip code, and contact information including, if possible, an email address and a mailing address. If the person refused to give the email address, they were asked to provide a mailing address; if the person still did not want to provide any contact addresses, then only the invitation letter was given.

If the intercepted beachgoers did not have access to the Internet, a mail survey was sent to their residency. To reduce recall bias, expenditure surveys should be conducted as soon after the recreational event as possible (Champ & Bishop, 1996). Therefore, three waves of email reminders were subsequently sent within two weeks after the date of each on-site sampling. The fourth wave of email reminder was sent after one month. Because some intercepted beachgoers left a resident address instead of an email address, we sent three waves of mail reminders in one month to those who gave residential address information. The survey had two parts: one asked people's itemized expenditures, and another collected demographic information. The spending survey instrument is presented in Appendix 3-A.

Results

During the 2014 summer period, 336 groups (parties) were intercepted at three beaches on the Great Lakes and invitation letters were successfully handed to 334 groups. By the end of survey period, we received 150 fully complete responses out of 170 overall responses. After replacing missing demographic information with mean values of the samples, we obtained 7 more useable responses, which leads to 157 effective observations, with a response rate of 47%.

Following Stynes (1997) and English (1997), a beachgoer's spending from the visitor survey is measured for the party. Party is defined in the survey as the persons arriving in the same vehicle. Therefore, party size is very important when transforming the spending per party to spending per person.

Dividing the spending per party by party size gives the average spending per person (Table 3.6). Compared to other spending studies such as Murray et al (2001) with a range of $18 to $24 in 1998 dollars, our day trip spending per person is comparatively lower with $15.57. One reason is that we differentiate the beachgoers within the state and outside of the state, and in these tables we only include the beachgoers who are Michigan residents.

Table 3.6 The average spending per person for Michigan beachgoers

Trip type	Mean ($)	Standard Deviation	Frequency
Day trip	15.57	17.96	104
Overnight trip	269.65	228.78	30
Stop over	94.92	113.20	6
Total	73.41	149.85	140

Table 3.7 presents the average spending per person across each beach site. People tended to spend more at Grand Haven, less at Saginaw Bay, and the least at St. Clair Metro Park.

Table 3.7 The average spending per person for each site for Michigan beachgoers. Saginaw Bay in bold.

Site	Mean ($)	Standard Deviation	Frequency
Grand Haven	102.33	171.39	90
Saginaw Bay	**39.62**	**128.01**	**18**
St. Clair Metro Park	11.11	16.35	32
Total	73.41	149.85	140

Table 3.8 displays the regional differences in the total spending of beach visitation per person per season. If we assume the trips taken by an average Michigan beachgoer during the beach season in 2011 maintains the same as in 2014, the total spending of an average beachgoer to Great Lakes beaches in one region ranges from $35.92 to $248.80 in 2014 dollars. Specifically, during a beach season, an average Michigan beachgoer spent $96.55 per person per season in Huron South (which includes Saginaw Bay).

Table 3.8 Economic impacts of beach visitation in 2014 dollars per person per season

	Number of Trips (per person per season)	Total Spending by Region (per person per season)
Huron North	0.68	99.51
Huron South	**0.69**	**96.55**
St. Clair	0.42	54.57
Erie	0.27	35.92
Michigan North	1.59	229.92
Michigan Central	1.72	248.80
Michigan South	0.97	140.95

To calculate the state level economic spending, we aggregated the weighted average regional spending per person to all beachgoers living in the Lower Peninsula. Table 3.9 displays the differences in the total regional spending for beach visitation at the state level. Beachgoers spent $408.26 million in the Huron South region.

Table 3.9 Economic impacts of total spending by region in 2014 dollars at state level

State level	mber of Trips (millions)	Total Spending by Region (millions)
Huron North	2.86	420.78
Huron South	2.93	408.26
St. Clair	1.79	230.74
Erie	1.16	151.90
Michigan North	6.73	972.19
Michigan Central	7.27	1052.00
Michigan South	4.11	596.01

Conclusions and Discussion (Section 2)

Spending analysis is an essential component of economic impact analysis. By using a visitor spending survey, this section aims to estimate trip spending to Great Lakes beaches in order to provide the spending information to enable the quantification of the contribution of beach recreation to local economies. The survey found visitors to Saginaw Bay spent an average of $39.62 at each site, much less than visitors to Grand Haven who spent an average of $102.33.

We further used the estimated spending equation to extrapolate an average beachgoer’s spending per season by using the 2011 Great Lakes Beaches Survey. We found the regional spending per season of an average beachgoer to Great Lakes beaches ranges from $35.92 to $248.80, with visitors spending an average of $96.55 in the Huron South region (which contains Saginaw Bay). This compares to $35.92 at Lake Erie (least) and $248.80 at Michigan Central (most).

3. Estimating the Economic Impacts of Changes in Water Quality by Linking a Recreational Demand System with Spending Data[5]

Quantifying the contributions of water quality improvements to local economies can inform policy makers about some of the importance of improving water quality, as well as illuminating some of the distributional implications of programs. Understanding the regional distribution of the economic impacts water quality improvements, however, requires measurement of these economic impacts. Specifically, the core question is: What do water quality improvements of the Great Lakes contribute to local economies?

Economic impact analysis is a tool to address the proceeding question. Following Stynes (1997), economic impact analysis for recreation traces the flow of spending associated with visitation in a given region in order to determine the effects of recreation on the sales, income, and employment of that region's residents. Quantifying the economic impacts of water quality improvement to the local economy can demonstrate some of the importance of improving water quality and help policy makers evaluate water quality restoration and improvement programs.

However, measuring the regional economic impacts from water quality improvements is very challenging. Because water quality is a public good, water quality improvements can benefit a range of different activities for different people at different levels. Therefore, one challenge lies in the complexity of identifying the group of beneficiaries from water quality improvements (Keeler et al, 2012). As Bockstael, Hanemann and Kling (1987) indicated, significant benefits from surface water quality improvements accrue to recreational use. Thus we consider recreational

[5] This section draws from Cheng and Lupi (2016b; 2016c) and Essays 3 and 4 of Cheng (2016), which contain the complete methods details, the necessary predictive equations, and prediction results.

beach use as the one of the beneficiaries and the medium to link water quality improvements of the Great Lakes and the local economic impacts.

This section builds on Section 1 and Section 2 to quantity the economic impacts from water quality changes. Specifically, there are two steps involved: the first step of is to measure the economic impacts of beaches to the local economy; the second step is to set up the linkages between water quality and beach recreation to estimate the economic impacts of water quality improvements. By integrating the recreation demand system from Section 1 and economic impact analysis from Section 2, this section establishes the critical linkages between water quality and beach recreation to estimate the regional economic impacts of access to beaches and the regional economic impacts of changes in water quality. This first objective for this chapter is to to estimate the economic impacts of beach recreation at regional levels. The second objective is to establish the critical linkages between water quality and beach recreation to estimate the economic impacts of water quality changes by region. By integrating the recreation demand system from Section 1 and spending analysis from Section 2, this section is able to establish the critical linkages between water quality, beach recreation and spending to estimate the economic impacts of water quality improvements.

Method

According to Bergstrom et al. (1996), when non-resident beachgoers take a trip to a region, the region basically "exports" the recreation services associated with the beach. The revenue generated from beachgoers stimulates the local economy by direct, indirect, and induced effects. For example, assume beachgoers dine in restaurants near the beach. In order to provide food to beachgoers, restaurants need to purchase food, which ultimately comes from farmers. This first-round purchase is a direct effect of spending. Farmers need to increase their production by purchasing more inputs, such as fertilizer, which leads fertilizer producers to increase purchases of their inputs to produce more of their product. These "chain effects" of additional purchases are considered indirect effects. Both the direct effect and the indirect effects of the beachgoer's spending stimulate the overall increase of production, along with the increased employment and income in the region. This increased income leads to more consumer demand, considered the induced effects.

Two surveys are applied in this section. The first one is the Great Lakes Beaches Survey, which was used in the recreation demand system in Section 1. The second survey is the Beach Visitor Spending Survey, which was used for the spending estimation in Section 2.

In the Great Lakes Beaches Survey, we used the trip data and choice experiment data. The trip data was collected by asking respondents' trips to public Great Lakes beaches in one summer season from Memorial Day weekend to September 30, 2011. The choice experiment data was gathered by asking respondents' preferred beach in each of three different choice sets with experimentally designed attributes. The trip data has 2,573 observations, 1,894 individuals took at least one trip to Great Lakes beaches during the beach season. The choice set for each individual consists of 451 beaches. The sample size of respondents for choice experiment data is 946, with 2,785 choice sets. Each choice set has two alternatives.

The Beach Visitor Spending Survey has 157 observations used for spending estimation, 336 observations were used to correct for response/nonresponse bias. The estimated spending equation was applied to 2,537 beachgoers from the Great Lakes Beaches Survey. Because each beachgoer has 451 beach alternatives in the choice set, the sample for prediction has 1,144,187 observations.

Results

Economic Impact of Beach Visitation by Region

This section provides the economic impacts of Great Lakes beaches visitors' spending on the local economy. Table 3.10 displays the regional differences in the economic impacts of beach visitation per person per season. The direct sales of an average beachgoer to Great Lakes beaches in one region ranges from $61.41 to $248.62 per season in 2014 dollars. If the sales multiplier for every region is 1.64 (Cook, 2009), the spending by an average Michigan beachgoer had a total economic impact of direct sales on one region that ranges from $100.72 to $407.74 per season. Specifically, during a beach season, an average Michigan beachgoer to Mid-East region generates the lowest total sales at $100.72, followed by Northeast region at $155.65. Beachgoers to Mid-West region have the highest total sales at $407.74 per person per season, followed by Northwest region at $368.94 per person per season.

Table 3.10 Economic Impacts of access to Great Lakes beaches by region in 2014 dollars. LP Mid-East includes Saginaw Bay (bold).

Per Person Per Season			
		Direct Sales	Total Sales
Access to Beaches	LP Northeast	94.91	155.65
	LP Mid-East	**61.41**	**100.72**
	LP Southeast	125.64	206.04
	LP Northwest	224.96	368.94
	LP Mid-West	248.62	407.74
	LP Southwest	140.92	231.11

	State level		
		Direct Sales (Million)	Total Sales (Million)
Access to Beaches	LP Northeast	401.30	658.13
	LP Mid-East	**259.68**	**425.87**
	LP Southeast	531.24	871.23
	LP Northwest	951.23	1560.00
	LP Mid-West	1051.30	1724.10
	LP Southwest	595.87	977.23

To calculate the state level economic impacts for access to beaches in each region, we aggregated the weighted average economic impacts per person to all beachgoers living in the Lower Peninsula. The population number of beachgoers is derived from the participation rate of beach recreation, which is 58.01%, multiplied by 7,289,085 Michigan adults living in the Lower Peninsula. Table 3.10 displays the regional differences in the economic impacts of beach visitation at the state level. Multiplied with the sales multiplier—1.64, the $259.68 million spent by beachgoers to Mid-East region had a total economic impact on the region of $425.87 million in direct sales, which is the lowest among the 6 regions. Visitors to the beaches in the Northeast region supported $658.13 million of total direct sales, which is the second lowest. By contrast, Michigan Central received the largest amount of total direct sales at $1.72 billion, followed by Michigan North at $1.56 billion and the Michigan South at $977.23 million. Figure 3.1 shows regional variation of the total sales at state level from beach visitation.

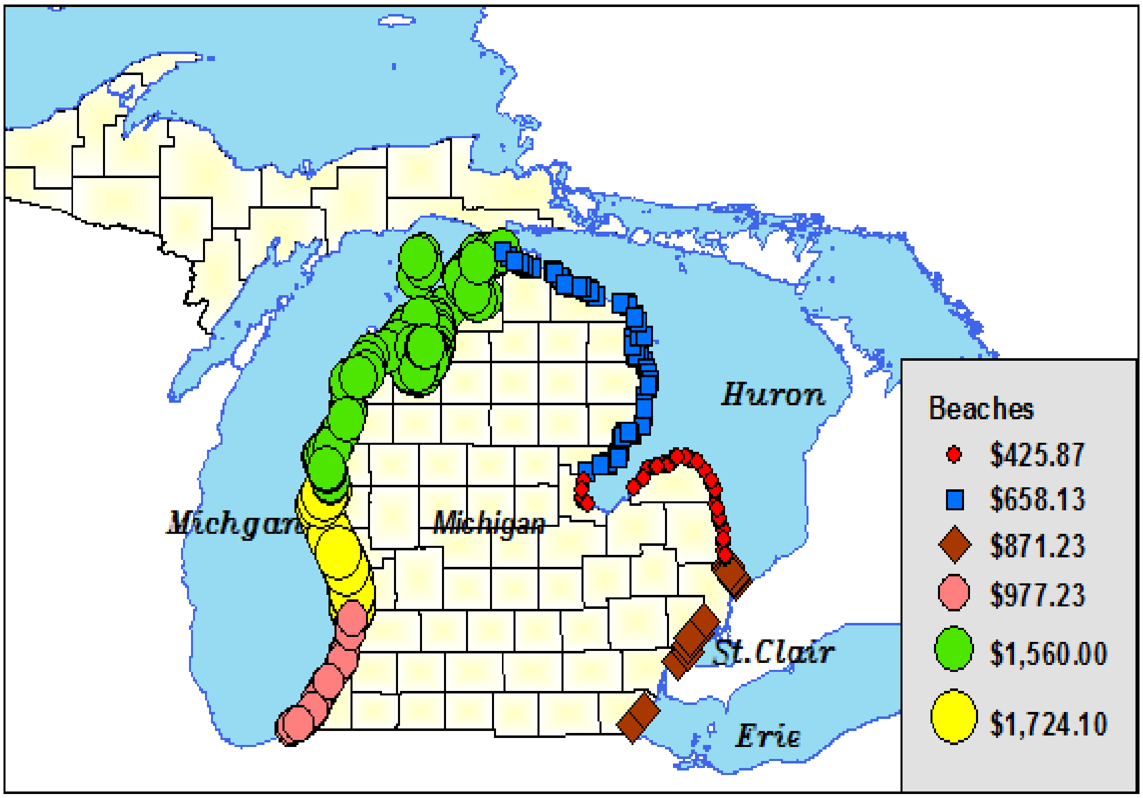


Figure 3.1 Total sales from beach visitation by region in 2014 dollars (millions).

Economic Impacts in Response to Water Quality Changes

As in Section 1, we consider two types of welfare scenarios using our calibrated joint model. The first scenario assumes that water quality at half of the sites in a region is improved *up* by one level. Simply put, half of Great Lakes beaches in a region with the high algae level are improved to the medium level and half of beaches in a region with the medium algae level are improved to the low level. The second scenario assumes that water quality is deteriorated by shifting half of the sites' water quality in a region *down* by one level. This is a significant change in water quality, because half of beaches with the low algae level are degraded to the medium level and half of beaches with the medium algae level are degraded to the high level. In both types of scenarios the algae changes are made only within one region at a time, resulting in twelve total welfare scenarios (an improvement and decrement to quality in each of six regions).

Table 3.11 displays the economic impact and the changes in the economic impact from the first scenario of water quality improvement. If we improve half of Great Lakes beaches' water quality in a region *up* by one level, compared to the direct sales at status quo, the direct sales increases by 33.52% for Middle-East region (Huron South) and 20.63% for Southeast region (St. Clair and Erie). Direct sales increase slightly for Huron North and Lake Michigan. The intuition behind this is that the baseline algae levels in Huron South, St. Clair, and Erie are higher than those in Huron North and Lake Michigan. Once we increase the water quality, the utility of a person is increasing as the algae level decreases. Therefore, improving water quality leads to more utility increase for beaches with initially higher algae levels in Huron South, St. Clair, and Erie than for beaches with initially lower algae levels in Huron North and Lake Michigan. In particular, direct sales from Southwest region never change, because the baseline water quality in the Southwest region was already at the highest level.

Under the water quality improvement scenario, the change of total sales of an average beachgoer to Great Lakes beaches in one region ranges from $0 to $42.50 per season in 2014 dollars. When aggregated at the state level, improvements of water quality in Southeast region (Lake St. Clair and Lake Erie) results in $179.7 million more total sales by all Michigan beachgoers living in the Lower Peninsula, which is the highest change of total sales in 6 regions, followed by Mid-East region with $142.76 million more total sales. Again, change of total sales from South

Michigan were zero because it had the highest water quality at status quo. Figure 3.2 shows the changed total sales from water quality improvement in a region in 2014 Dollars at the state level.

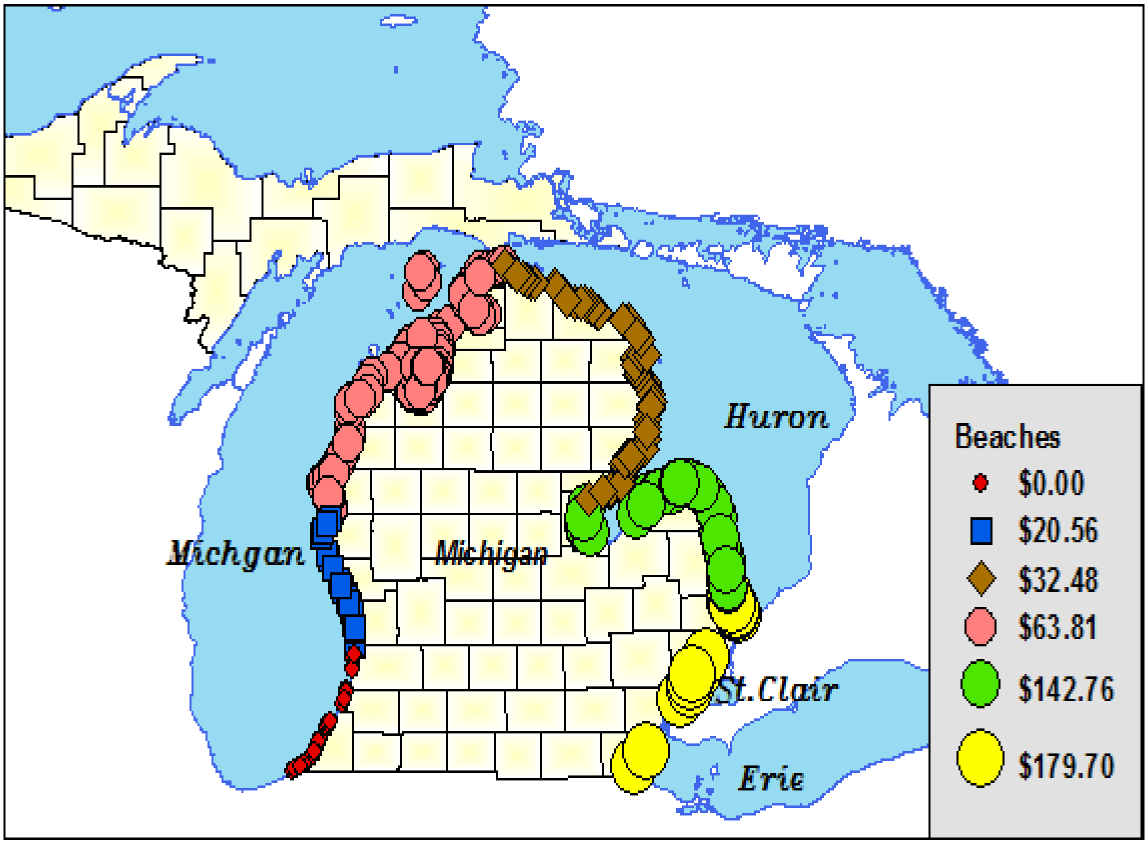


Figure 3.2 Changed total sales from improving water quality by one level at half of the sites in a region in 2014 dollars (millions).

By contrast, if we degrade half of Great Lakes beaches' water quality in a region *down* one level, direct sales decrease dramatically and loss of total sales turns out to be significant. Table 3.12 displays the economic impact and changes in economic impacts from the second scenario of the water quality deterioration. Compared to the direct sales at status quo, all regions lose sales and the magnitude of decreased direct sales ranges from 23.87% to 32.58% across the six regions. When aggregated at the state level, 421.12 million total sales are lost in the Northwest region due to degrading half of Great Lakes beaches' water quality in that region *down* by one level. Mid-west region loses $411.61 million total sales, followed by Southwest region losing $246.12

million total sales. Mid-East region loses $138.76 million total sales, which is the least sales loss among the six regions. The range of total sales loss indicates that the water quality degradation impacts Lake Michigan most and Huron south least. Figure 3.3 shows the changed total sales from water quality degradation in a region in 2014 Dollars at the state level.

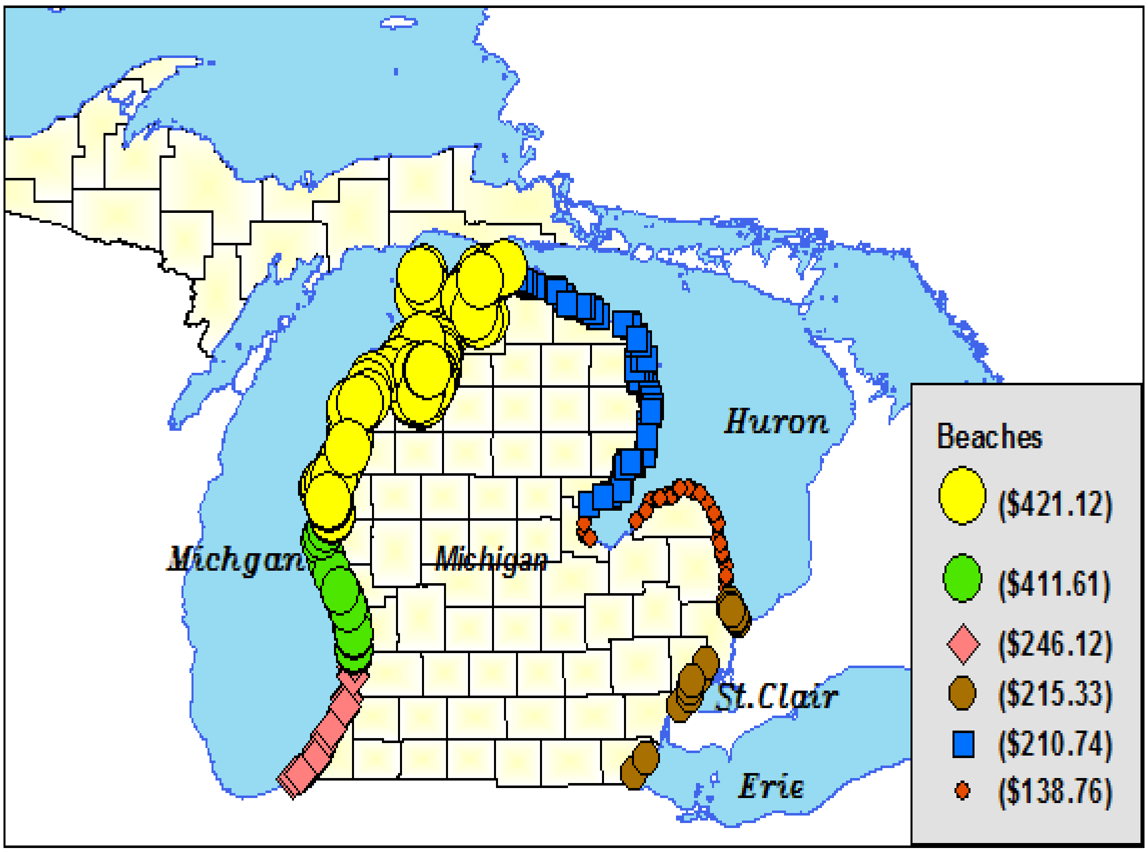


Figure 3.3 Changed total sales from decreasing water quality by one level at half of the sites in a region in 2014 dollars (millions)

Table 3.11 Changes in economic impacts from improving water quality by one level at half of sites in a region in 2014 dollars. LP Mid-East includes Saginaw Bay (bold).

Per Person Per Season						
		Direct Sales	Total Sales	Change of Direct Sales	% Change in Direct Sales	Change of Total Sales
Take Half of Sites' Algae in the Water & Algae on the Shore *up* by one Level	LP Northeast	99.59	163.33	4.68	4.94%	7.68
	LP Mid-East	**82.00**	**134.48**	**20.59**	**33.52%**	**33.76**
	LP Southeast	151.55	248.54	25.91	20.63%	42.50
	LP Northwest	234.16	384.03	9.20	4.09%	15.09
	LP Mid-West	251.59	412.60	2.96	1.19%	4.86
	LP Southwest	140.92	231.11	0.00	0.00%	0.00

			State level			
		Direct Sales (Million)	Total Sales (Million)	Change of Direct Sales (Million)	% Change in Direct Sales	Change of Total Sales (Million)
Take Half of Sites' Algae in the Water & Algae on the Shore *up* by one Level	LP Northeast	421.10	690.61	19.80	4.94%	32.48
	LP Mid-East	**346.73**	**568.64**	**87.05**	**33.52%**	**142.76**
	LP Southeast	640.82	1050.90	109.58	20.63%	179.70
	LP Northwest	990.14	1623.80	38.91	4.09%	63.81
	LP Mid-West	1063.80	1744.70	12.54	1.19%	20.56
	LP Southwest	595.87	977.23	0.00	0.00%	0.00

Table 3.12 Changes in economic impacts from decreasing water quality by one level at half of the sites in a region in 2014 dollars. LP Mid-East includes Saginaw Bay (bold).

Per Person Per Season						
		Direct Sales	Total Sales	Change of Direct Sales	% Change in Direct Sales	Change of Total Sales
Take Half of Sites' Algae in the Water & Algae on the Shore *down* by one Level	LP Northeast	64.52	105.81	-30.39	-32.02%	-49.84
	LP Mid-East	**41.40**	**67.90**	**-20.01**	**-32.58%**	**-32.82**
	LP Southeast	94.59	155.12	-31.05	-24.71%	-50.92
	LP Northwest	164.23	269.34	-60.73	-27.00%	-99.59
	LP Mid-West	189.27	310.40	-59.36	-23.87%	-97.34
	LP Southwest	105.43	172.90	-35.49	-25.19%	-58.21

			State level			
		Direct Sales (Million)	Total Sales (Million)	Change of Direct Sales (Million)	% Change in Direct Sales	Change of Total Sales (Million)
Take Half of Sites' Algae in the Water & Algae on the Shore *down* by one Level	LP Northeast	272.80	447.39	-128.50	-32.02%	-210.74
	LP Mid-East	**175.07**	**287.11**	**-84.61**	**-32.58%**	**-138.76**
	LP Southeast	399.94	655.91	-131.30	-24.71%	-215.33
	LP Northwest	694.45	1138.90	-256.78	-27.00%	-421.12
	LP Mid-West	800.30	1312.50	-250.98	-23.87%	-411.61
	LP Southwest	445.80	731.11	-150.07	-25.19%	-246.12

Conclusions (Section 3)

Section 3 estimated regional variation in economic impacts from trips to Great Lakes beaches in Michigan. By integrating the recreation demand system from Section 1 and spending analysis from Section 2, this section established the critical linkages between water quality and beach recreation to estimate the economic impacts of water quality improvements. By constructing two types of water quality scenarios, this section further estimated the changes in economic impacts to the local region when water quality changes.

In considering the impacts of a loss of access to beaches within a region, we found the spending by all Michigan beachgoers living in the Lower Peninsula had a total economic impact of direct sales within a region that ranged from $425.87 million to $1.72 billion per season in 2014 dollars. Michigan Central received the largest amount of total direct sales at $1.72 billion, in contrast to Huron South region (which contains Saginaw Bay) with the lowest total sales at $425.87 million.

If we improve half of Great Lakes beaches' water quality in a region up by one level, compared to the direct sales at status quo, the direct sales increases by 33.52% for Mid-East region (Huron South). The intuition behind this is that the baseline algae levels in Huron South, St. Clair, and Erie are higher than those in Huron North and Lake Michigan. Once we increase the water quality, the utility of a person is increasing as the algae level decreases. Therefore, improving water quality leads to more utility increase for beaches with initially higher algae levels in Huron South, St. Clair, and Erie than for beaches with initially lower algae levels in Huron North and Lake Michigan. When aggregated at the state level, improvements of water quality in Southeast region (Lake St. Clair and Lake Erie) results in $179.7 million more total sales by all Michigan beachgoers living in the Lower Peninsula, which is the highest change of total sales in 6 regions, followed by Mid-East region with $142.76 million more total sales. When water degrades by one level, the LP Mid-East region loses $138.76 million total sales, which is the least sales loss among the six regions.

The results of Section 3 can demonstrate the contribution of beach recreation, some of the importance of improving water quality, and help policy makers to evaluate water quality restoration and improvement programs.

Summary of the Economic Analyses

As mentioned in the introduction the economic analyses present information on two very distinct economic concepts that relate to the quality of beaches and beach visitation: (1) *economic values* to beach visitors and (2) beach-related spending and the associated *economic impacts* for the economy. The economic modelling relied on recreational demand models to predict trips to beaches and to measure the *economic value* of these trips to the beachgoers (the consumer surplus estimates) and combined the demand models with spending estimation to predict *economic impacts* to regional economies. In general it is not appropriate to simply add economic impacts and values together so care is warranted in their use.

The results of the modelling work were presented at regional levels because the results would be more reliable at the regional spatial scale than at the scale of an individual beach. Never-the-less, it is worth noting that the models predict the Huron South region (which contains the BCSRA) receives just under 7% of the beach visits in the lower peninsula of Michigan. The Huron South region contains 42 beaches, and the BCSRA is a popular site that receives about 8% of the predicted trips to the region. From the overall data and the modeling results, it was very clear that all else equal, beachgoers prefer Great Lakes beaches in other regions, especially beaches on Lake Michigan—beaches in the Huron South region had the lowest baseline visitation of any region. Despite the general preference for beaches in other regions, the results suggest that improvements in water quality in the Huron South region would yield significant economic benefits to beachgoers and increase the economic impacts of trips to the region, though the region's beaches would likely remain less popular than the Lake Michigan regions or the Southeast Michigan region.

References

Adamowicz, Wiktor, Swait, Joffre, Boxall, Peter, Louviere, Jordan, & Williams, Michael. (1997). Perceptions versus objective measures of environmental quality in combined revealed and stated preference models of environmental valuation. *Journal of Environmental Economics and Management, 32*(1), 65-84.

Austin, J, and A. Steinman. (2015). *Michigan's Blue Economy Report*. Retrieved from http://michiganblueeconomy.org/wp-content/uploads/2015/03/Michigan-Blue-Economy-Report.pdf

Bergstrom, J. C., Teasley, R. J., Cordell, H. K., Souter, R., & English, D. B. (1996). Effects of reservoir aquatic plant management on recreational expenditures and regional economic activity. *Journal of Agricultural and Applied Economics, 28*(2), 409.

Bockstael, Nancy E, Hanemann, W Michael, & Kling, Catherine L. (1987). Estimating the value of water quality improvements in a recreational demand framework. *Water Resources Research, 23*(5), 951-960.

Champ, P. A., & Bishop, R. C. (1996). Evidence on the accuracy of expenditures reported in recreational surveys. *Journal of Agricultural and Resource Economics*, 150-159.

Chen, Min. (2013). *Valuation of public Great Lakes beaches in Michigan*, PhD Dissertation, Michigan State University

Cheng, Li. (2016). *Measuring the value and economic impacts of changes in water quality at Great Lakes beaches in Michigan*, PhD Dissertation, Michigan State University

Cheng, L., & F. Lupi (2016a). Combining revealed and stated preference data with large choice sets: valuing water quality changes to Great Lakes beaches in Michigan, AAEA conference selected paper, Boston MA July 2016.

Cheng, L., & F. Lupi (2016b). Estimating visitor spending for trips to Great Lakes beaches in Michigan, working paper, Michigan State University.

Cheng, L., & F. Lupi (2016c). Estimating economic impacts of changes in water quality by linking a recreational demand system and spending data, working paper, Michigan State University.

Cook, P.S. (2011). *Impacts of visitor spending on the local economy: Sleeping Bear Dunes National Lakeshore, 2009*. Natural Resource Report. National Park Service, Fort Collins, Colorado.

Deisenroth, D. B., Loomis, J. B., & Bond, C. A. (2013). Using Revealed Preference Behavioral Models to Correctly Account for Substitution Effects in Economic Impact Analysis. *Journal of Regional Analysis & Policy, 43*(2), 157.

Egan, Kevin J, Herriges, Joseph A, Kling, Catherine L, & Downing, John A. (2009). Valuing water quality as a function of water quality measures. *American Journal of Agricultural Economics, 91*(1), 106-123.

English, D. B. (1997). Effects of sample selection on estimates of economic impacts of outdoor recreation. *The Review of Regional Studies, 27*(3), 219.

Freeman III, A Myrick, Herriges, Joseph A, & Kling, Catherine L. (2014). *The measurement of environmental and resource values: theory and methods*. Oxon: RFF Press.

Greene, W. H. (2003). *Econometric analysis*: Pearson Education.

Griffiths, C., Klemick, H., Massey, M., Moore, C., Newbold, S., Simpson, D., . . . Wheeler, W. (2012). US Environmental Protection Agency valuation of surface water quality improvements. *Review of Environmental Economics and Policy, 6*(1), 130-146.

Kannel, Prakash Raj, Lee, Seockheon, Lee, Young-Soo, Kanel, Sushil Raj, & Khan, Siddhi Pratap. (2007). Application of water quality indices and dissolved oxygen as indicators for river water classification and urban impact assessment. *Environmental Monitoring and Assessment, 132*(1-3), 93-110.

Keeler, Bonnie L, Polasky, Stephen, Brauman, Kate A, Johnson, Kris A, Finlay, Jacques C, O'Neill, Ann, Kovacs, kent, & Dalzell, Brent. (2012). Linking water quality and well- being for improved assessment and valuation of ecosystem services. *Proceedings of the National Academy of Sciences, 109*(45), 18619-18624.

Kneese, A. V., & Bower, B. T. (1968). *Managing water quality: economics, technology, institutions*: Baltimore: Resources for the Future, Johns Hopkins Press..

Murray, Chris, Sohngen, Brent, & Pendleton, Linwood. (2001). Valuing water quality advisories and beach amenities in the Great Lakes. *Water Resources Research, 37*(10), 2583-2590.

Natural Resources Defense Council. (2009). *Testing the Waters: A Guide to Water Quality at Vacation Beaches*, 19th edition. Retrieved from http://www.nrdc.org/water/oceans/ttw/ttw2009.pdf

Stynes, D. J. (1997). Economic impacts of tourism: a handbook for tourism professionals. *Urbana, IL: University of Illinois, Tourism Research Laboratory*, 1-32.

U. S. Environmental Protection Agency. (1989). *Measuring the Benefits of Water Quality Improvements Using Recreation Demand Models: Part 1* (EPA Contract No. CR-811043- O1-O).

U.S. EPA. (2008). "Great Lakes Beach Sanitary Survey User Manual." Office of Water. EPA-823-B-06-001. May. Retrieved from http://water.epa.gov/type/oceb/beaches/upload/2008_05_29_beaches_sanitarysurvey_use r-manual.pdf

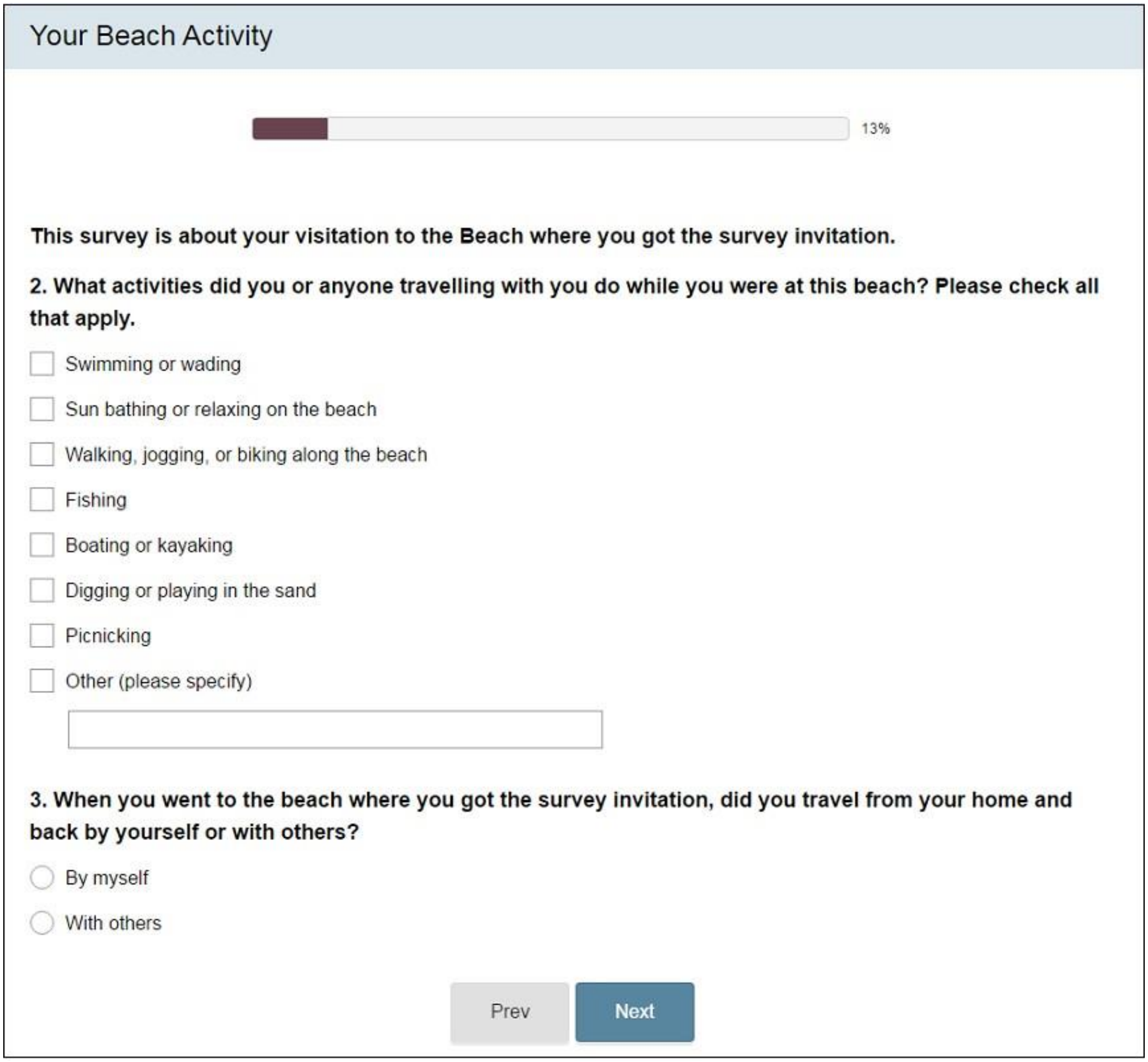
Verhougstraete, M., Rose, J., Byappanahalli, M., & Whitman, R. L. (2010). Cladophora in the Great Lakes: impacts on beach water quality and human health. *Water Science & Technology, 62*(1).

Watson, P., J. Wilson, D. Thilmany and S. Winter. (2007). Determining economic contributions and impacts: What is the difference and why do we care? *J. of Regional Analysis and Policy*. *37*(2):1-15.

Weicksel, Scott Arndt. (2012). *Measuring Preferences for Changes in Water Quality at Great Lakes Beaches Using a Choice Experiment.* Master Thesis, Michigan State University.

Appendix 3-A

Beach spending web survey instruments



Your Beach Activity

13%

This survey is about your visitation to the Beach where you got the survey invitation.

2. What activities did you or anyone travelling with you do while you were at this beach? Please check all that apply.

- [ ] Swimming or wading
- [ ] Sun bathing or relaxing on the beach
- [ ] Walking, jogging, or biking along the beach
- [ ] Fishing
- [ ] Boating or kayaking
- [ ] Digging or playing in the sand
- [ ] Picnicking
- [ ] Other (please specify)

3. When you went to the beach where you got the survey invitation, did you travel from your home and back by yourself or with others?

- ○ By myself
- ○ With others

Prev Next

Appendix 3-A-(cont'd)

Visitation Information

50%

4. What type of transportation did you use to get to the beach where you got the survey invitation?

- ◯ Vehicle
- ◯ Bike
- ◯ Walk
- ◯ Other (please specify)

[ ]

Prev | Next

Visitation Information

56%

5. Including yourself, how many people traveled in the same vehicle?

[ ]

*** 6. Which of the following best decribes the type of trip you took to the beach where you got the survey invitation?**

- ◯ Day Trip (a trip from your home and back in one day)
- ◯ Overnight Trip (a trip from your home and back extended over at least one night)
- ◯ Just a stopover (the beach was not my primary destination, just a stopping place on other travel)

Prev | Next

Appendix 3-A-(cont'd)

Expenditure for Day Trip

63%

* **7. Please enter the dollar amount of expenditures <u>you and the people that traveled in the same vehicle as you</u> made for this trip to <u>the beach where you got the survey invitation</u>. Do this for each category below. Please be as accurate as possible - If unsure, provide your best estimate. If you made no expenditures for a spending category, please enter a "0".**

Gas and oil (auto, RV, boat, etc)	
Car Rental, Airfares, Taxi, Bus	
Restaurants and Bars	
Groceries and Take-out Food/Drink	
Park Access Fee	
Entertainment fees (boat renting, fishing, etc)	
Sporting goods (volleyball, life vest, etc)	
Clothing	
Souvenirs/gifts/postcards	
Other	

Prev Next

Appendix 3-A-(cont'd)

Your Trip Frequency

88%

8. Please think about the beach where you got the survey invitation.

Including the time we met, how many trips have you taken to this beach since Memorial Day weekend (May 24th, 2014)?

9. Please think about any Great Lakes beaches in Michigan.

Including the time we met, how many trips have you taken to any Great Lakes beaches since Memorial Day weekend (May 24th, 2014)?

Prev Next

About You

94%

10. Who is filling out this survey?

- The person the invitation was given/addressed to
- Another household member
- Someone else

11. What is your gender?

- Male
- Female

12. In what year were you born?

Appendix 3-A-(cont'd)

13. What is the highest degree or level of schooling you have completed?

- ◯ Less than High School
- ◯ High School or equivalent
- ◯ Some College, no degree
- ◯ Associate's degree
- ◯ Bachelor's degree
- ◯ Graduate or Professional degree

14. What is the zip code of the place you live?

15. What is your current employment status?

- ☐ Employed Full Time
- ☐ Employed Part Time
- ☐ Unemployed
- ☐ Stay at home parent
- ☐ Retired
- ☐ Student

Appendix 3-A-(cont'd)

16. Do any of the following live in your household? (check all that apply)

- ☐ Spouse or significant other
- ☐ Children age 5 and under
- ☐ Children age 6-17
- ☐ Other immediate family
- ☐ Extended family or other adults
- ☐ None of these

17. What is your approximate annual household income? (check one)

- ○ Less than $24,999
- ○ $25,000 to $34,999
- ○ $35,000 to $49,999
- ○ $50,000 to $74,999
- ○ $75,000 to $99,999
- ○ $100,000 to $149,999
- ○ $150,000 to $199,999
- ○ $200,000 or more

Prev Next

Thank You

100%

Thank you for completing this survey.

Prev Done

Appendix 3-A (cont'd)

Lodging for Overnight Trip

69%

7. Where did you stay during your visit?

- Stayed at hotel or motel
- Rented a house, condo, or apartment
- Campground
- Stayed in your own property
- Stayed at family or friends' place
- Other (please specify)

Prev Next

Appendix 3-A-(cont'd)

Expenditure for Overnight Trip

75%

* 8. **Expenditures made *Within 35 Miles* of the Beach Destination**

For the beach where you got the survey invitation, please enter the dollar amount of expenditures you and the people that traveled in the same vehicle as you made Within 35 miles of the beach destination. Do this for each category below. Please be as accurate as possible - If unsure, provide your best estimate. If you made no expenditures for a spending category, please enter a "0".

Hotels, motels, Cabins

Campground Fees

Gas and oil (auto, RV, boat, etc)

Car Rental, Airfares, Taxi, Bus

Restaurants and Bars

Groceries and Take-out Food/Drink

Park Access Fee

Entertainment fees (boat renting, fishing, etc)

Sporting goods (volleyball, life vest, etc)

Clothing

Souvenirs/gifts/post cards

Other

* 9. **Expenditures made *Outside 35 Miles* of the Beach Destination**

For the beach where you got the survey invitation, please enter the dollar amount of expenditures you and the people that traveled in the same vehicle as you made Outside 35 miles of the beach destination. Do this for each category below. Please be as accurate as possible - If unsure, provide your best estimate. If you made no expenditures for a spending category, please enter a "0".

*If you traveled less than 35 miles to reach the beach destination, enter a "0" for all categories.

Hotels, motels, Cabins

Campground Fees

Gas and oil (auto, RV, boat, etc)

Car Rental, Airfares, Taxi, Bus

Restaurants and Bars

Groceries and Take-out Food/Drink

Park Access Fee

Entertainment fees (boat renting, fishing, etc)

Sporting goods (volleyball, life vest, etc)

Clothing

Souvenirs/gifts/post cards

Other

Prev Next

Appendix 3-A-(cont'd)

Expenditure for Your Stopover

44%

*** 6. Expenditures made *Within 35 Miles* of the Beach**

For the beach where you got the survey invitation, please enter the dollar amount of expenditures you made Within 35 miles of the beach. Do this for each category below. Please be as accurate as possible - If unsure, provide your best estimate. If you made no expenditures for a spending category, please enter a "0".

Hotels, motels, Cabins

Campground Fees

Gas and oil (auto, RV, boat, etc)

Car Rental, Airfares, Taxi, Bus

Restaurants and Bars

Groceries and Take-out Food/Drink

Park Access Fee

Entertainment fees (boat renting, fishing, etc)

Sporting goods (volleyball, life vest, etc)

Clothing

Souvenirs/gifts/postcards

Other

Prev Next

Chapter 4: Public perception of causes and impacts of muck and credibility of associated agencies

For more than 50 years, regions of the Great Lakes, including Saginaw Bay, have occasionally experienced accumulations of organic detritus along the shoreline (Higgins, et al., 2008; Verhougstraete, et al., 2010). This debris—commonly known as muck—may be comprised of decomposing algae, macrophytes, phyto- and zoo-plankton, can emit a noxious odor, and harbor high levels of fecal indicator bacteria (Byappanahalli, et al., 2003). In recent years, there is some evidence that muck accumulations have increased (Barton, Howell, & Fietsch, 2013), in some cases reaching levels that can severely degrade shoreline aesthetics and interfere with recreational beach use (Harris, 2004). This increase in the temporal duration and spatial distribution of muck has been attributed to a variety of factors, including excessive nutrient inputs, increasing water clarity due to invasive mussels, and rising water temperatures (National Oceanic & Atmospheric Administration [NOAA], 2013; Winslow, Francoeur, & Peacor, 2014). Nevertheless, significant questions remain about the specific causes, consequences, and solutions to these nuisance muck conditions.

In Bay City, Michigan, these beach fouling events can render the Bay City State Recreation Area (BCSRA), located in the southwestern corner of Saginaw Bay, unusable for local citizens. Many citizens, frustrated by the severity and persistence of this problem, have expressed a desire for federal and state agencies managing areas in and nearby the BCSRA to take more aggressive action on this issue. However, these agencies face resource constraints and legal mandates that may limit their ability to implement the management strategies that citizens want. Agencies have asserted that more needs to be known about the natural and anthropogenic factors driving muck formation and deposition before effective management strategies can be identified. Given the nature of the problem, agencies have also argued that clearing muck to the extent citizens expect may not be feasible. This lack of scientific clarity and inability to take satisfactory action has been an on-going source of conflict between citizens and resource management agencies.

As this problem has persisted, resource management agencies and local citizens have both had many opportunities to directly and indirectly experience accumulations of beach muck and develop their own ideas about what muck is, where it comes from, and what should be done about it. Gaining a better understanding of the beliefs, perceptions, and attitudes that these parties have regarding this issue is critical not only for improving communication and fostering participation, but also for identifying points of agreement and disagreement which could be used to alleviate the contentions that have arisen.

With this goal in mind, this portion of the integrated assessment focused on investigating stakeholder perceptions associated with various aspects of beach muck. Importantly, efforts were made to assess how both agency representatives and local citizens felt about a variety of muck related issues, including causes of muck, impacts associated with muck conditions, agency response, and management options. This sampling strategy allowed the perceptions of agency representatives to be directly compared with those of local citizen stakeholders in order to more clearly identify areas of agreement and disagreement.

This investigation utilized two methods to assess these perceptions. First, interviews were conducted with a select group of agency representatives and citizens stakeholders in and around Bay City. During these interviews participants completed a Conceptual Content Cognitive Mapping (3CM) exercise designed to explore how individuals conceptualized the muck issue. Results from the 3CM exercise were then used to inform the development of an online survey instrument that was distributed to a larger sample of agency representatives and local citizens. Part I of this report describes the 3CM process and compares the resulting maps generated by agency representatives and citizens. Part II describes the content of the online survey and the coorientation framework that was used to guide survey development. Finally, results of the online survey are presented for agency representatives and citizen participants.

Conceptual Content Cognitive Mapping (3CM)

In order to initially explore perceptions of muck a series of interviews were conducted with agency representatives and citizen stakeholders. Each interview was built around the completion of a Conceptual Content Cognitive Mapping exercise. This technique has previously been used to explore perceptions about a number of resource management issues, such as hazardous waste facility placement (Austin, 1994), forest management practices (Kearney, et al., 1998), and sustainable development (Byrch, et al., 2007). Essentially, 3CM is a card sorting exercise that reveals one’s knowledge structure about a particular issue (Kearney & Kaplan, 1997). Through this process it is possible to not only identify the specific content that is most salient to an individual, but also see how this content is organized (Kearney, 2015). The result of the 3CM exercise is a mental map that includes various clusters of important and interrelated items. These individual maps are combined across participants to create two aggregate mental maps, one for agency representatives and one for citizens.

Methods

In order to generate this mental map, each 3CM interview began by asking participants the following question:

"Imagine someone you know recently heard about beach muck in Saginaw Bay or at the Bay City State Recreation Area. Since you are familiar with the area, community, and/or issue they are interested in getting your perspective. What are the things you would be most likely to mention when discussing this issue?"

Participants were then given blank cards and asked to write responses or concepts on each card. Once participants finished generating items, they were given a set of 48 pre-generated response cards and told to select any additional responses they felt were appropriate and worth including (see Appendix 4-A for a full list of these responses). Once this process was complete participants were asked to organize the cards into categories and then create descriptive names for each category they had created. Next, participants were asked to briefly describe each category so the underlying meanings and category structures could be more accurately captured. The cards were then collected and the structure of the emergent categories was recorded. Although, no two participants selected the exact same set of items or created the same categories, meaningful and cohesive groupings were identified from across the participants' data using hierarchical cluster analysis. Each 3CM interview lasted approximately 30-45 minutes.

3CM Participants

Twenty-one (N=21) 3CM interviews were conducted during the summer of 2014. These participants were identified with the help of staff from the Michigan Department of Natural Resources, Michigan Department of Environmental Quality, and Michigan Sea Grant. In total, eleven (n=11) 3CM interviews were conducted with individuals who represented different agencies addressing the muck issue. This group was comprised of Great Lakes researchers and representatives of various regulatory agencies, such as the Michigan Department of Natural Resources (DNR), Michigan Department of Environmental Quality (DEQ), and the U.S. Army Corps of Engineers. The remaining ten (n=10) 3CM interviews were conducted with citizen representatives and local government officials from Bay City.

3CM Analysis

In order to compare the perspectives of agency representatives and local citizens, 3CM data from each group was analyzed independently using a Ward Hierarchical Cluster Analysis (HCA) in R (R Core Team 2015). HCA is a common method for analyzing card sorting results since it indicates how similar items are to one another. This allows the researcher to identify groups or categories of items that are more closely related. Once categories are identified, researchers assign a short descriptive name to reflect the overall concept represented.

Results and Discussion

Although the hierarchical cluster analysis identified three very similar clusters of responses for both agency representatives and citizens, the content and organization of these categories differed in important and interesting ways (see Table 4.1).

The first cluster, *Causes*, related to the underlining factors that contribute to beach muck. Both groups identified a large and diverse set of factors that were responsible for the formation and deposition of muck. There was also a good deal of agreement about the items that comprised this cluster. However, agency representatives tended to distinguish natural processes, which are more difficult to alter, from human inputs, such as nutrient loading. Neither of these sub-clustered emerged from the analysis of citizen 3CM data. Comments by some agency representatives during 3CM interviews alluded to this difference by indicating that citizens did not fully appreciate the fact that muck may be a natural part of the Saginaw Bay ecosystem. While the citizens in our sample did not make this distinction, it should be noted that they did identify several items related to natural factors (i.e., water clarity, invasive mussels, water temperature) indicating some awareness that natural processes do play a role.

The second cluster, which was labeled *Consequences*, included items associated with the impacts of beach muck. Two distinct and very similar sub-clusters were identified by both agency representatives and citizens. One of these sub-clusters related to personal, individual-level impacts and included items about health concerns, aesthetics, and frustration with current conditions. The other sub-cluster related to broader, community-wide impacts that result from beach muck. While the items that comprised this sub-cluster were fairly analogous for agency representatives and citizens, there was some indication and citizens placed greater priority on the fact the muck had a negative impact on the local economy. Likewise, citizens were more likely to identify that muck has had a negative impact on overall quality of life.

The final cluster, *Management*, was made up of items that related to the action taken by agencies and citizens to address beach muck. Once again, multiple distinct and similar sub-clusters emerged for agency representatives and citizens. The first shared sub-cluster concerned efforts to educate and inform the public about the larger Saginaw Bay ecosystem and beach muck specifically. During 3CM interviews both groups acknowledged the value of education and outreach; however, some citizens were quick to point out that education alone was not enough; they also had a strong desire to see management actions accompany outreach efforts. The next sub-cluster identified by both groups involved issues related to direct physical removal of muck from the beachfront and/or the near-shore waters. It is worth noting that physical removal was discussed extensively during the 3CM interviews of many agency representatives and citizens; however the content of these discussions differed slightly. Agency representatives were much more likely to mention the challenges associated with regular beach grooming. The fact that "cost/feasibility of removal" was a highly-endorsed item within this sub-cluster may speak to these concerns among agencies. The third shared sub-cluster related to the overall challenges associated with managing beach muck. The majority of agency representatives and citizens seemed to recognize that many factors influence muck formation and deposition and that this makes it difficult to identify effective management strategies. Despite this acknowledgement, citizen participants still expressed a strong desire for action.

A sub-cluster associated with regulatory issues also emerged for both groups, but the way agency representatives and citizens discussed the content of this sub-cluster differed significantly. Agency representatives tended to discuss agency responsibilities; emphasizing the need to consider ecosystem impacts and regulatory mandates when considering management options. Agency representatives also discussed the important role that research plays in helping them balance these responsibilities and determine appropriate management strategies. Interestingly, citizens were much more likely to see research as part of education and outreach efforts. Instead of focusing on agency responsibilities, citizens tended to discuss regulation as a barrier to taking action. Some citizens expressed frustration about the lack of consistency and coordination between various state and federal agencies. The final sub-category that emerged only for agency representatives encompassed a variety of alternative management strategies, such as installing physical barriers to prevent muck accumulation and working with communities across the larger watershed to reduce nutrient runoff.

Table 4.1. Hierarchical cluster analysis results of 3CM interviews

Category name and items included by ***agency representatives*** (frequency item mentioned)	Category name and items included by ***citizens*** (frequency item mentioned)
CAUSES	CAUSES
Natural Factors	Algae (8)
Algae (9)	Agricultural runoff (7)
Invasive mussels (8)	Leaking septic (7)
Wind and wave action (8)	Fertilizer (7)
Water clarity (7)	Nutrient loading (6)
Climate change (5)	Phosphorous levels (6)
Water temperature (3)	Water clarity (6)
	Nitrogen levels (6)
Human Inputs	Water pollution (5)
Phosphorous levels (9)	Invasive mussels (5)
Agricultural runoff (7)	Regulation of runoff (5)
Nutrient loading (7)	Water temperature (4)
Nearby land management (6)	
Water pollution (6)	
Fertilizer (6)	
Leaking septic (5)	
Sewage treatment overflows (3)	
Nitrogen levels (3)	
CONSEQUENCES	CONSEQUENCES
Personal Impacts	Personal Impacts
Health concerns (8)	Bad odor (9)
Citizen frustration (8)	Health concerns (9)

Bad odor (7)	Citizen frustration (8)
Community Impacts	Community Impacts
Beach use (8)	Economic impacts (10)
Recreation (7)	Impacts of tourism (10)
Economic impacts (6)	Recreation (10)
Impacts of tourism (6)	Beach use (9)
Pristine beachfront (7)	Change in quality of life (9)
Change in quality of life (3)	Commercial pier (7)
MANAGEMENT	MANAGEMENT
Education/Outreach	Education/Outreach
Education about the bay (8)	Scientific research (6)
Outreach/communication (7)	Outreach/communication (5)
Public meetings (6)	Education about the bay (4)
	Public meetings (4)
Removal	
Cost/feasibility of removal (7)	Removal
Beach grooming (7)	Beach grooming (9)
Physical removal of muck (7)	Physical removal of muck (8)
Muck filtering machine (5)	Muck filtering machine (8)
Disposal of muck (4)	Disposal of muck (8)
Regulatory Responsibilities	Regulatory Barriers
Scientific research (9)	Nearby land management (5)
Wetland protection (5)	Pristine beachfront (5)
Preservation of nature (5)	Cost/feasibility of removal (5)
Harm to wildlife (5)	Wetland protection (3)
	Preservation of nature (2)
Challenges	
Complexity of problem (9)	Challenges
Lack of clear solutions (7)	Agency response (8)
Agency response (7)	Lack of clear solutions (6)
Regulation of runoff (4)	Park management (6)
	Complexity of problem (4)
Alternative strategies	
Work with communities (6)	
Increase of muck over time (5)	
Physical barriers (4)	
Commercial pier (3)	
Park management (2)	

Survey of agency representatives and local citizens

Findings from 3CM interviews were used to inform the development of an online survey instrument. This survey was constructed so that muck-related perceptions and attitudes of agency representatives and local citizens could be compared to one another. Given this goal, portions of the survey instrument were designed using a coorientation framework.

Originally developed within the context of communication theory (Newcomb, 1953; McLeod & Chaffee, 1973), coorientation has been used to better understand the views of citizens and decision-makers regarding a variety of natural resource management issues, such as land use planning (Twight & Paterson, 1979), ecosystem restoration (Connelly & Knuth, 2002), and wildlife management (Leong, McComas, & Decker, 2008; Carrozzino-Lyon, McMullin, & Parkhurst, 2014). The premise of this framework is that behavior is not only a function of personal perceptions about an issue but is also based on perceptions of how others see the issue and how well these views align. As a result, coorientation asks people about their own beliefs, attitudes, and preferences, and asks these same individuals to make predictions about what other parties think. Responses of various groups can then be compared to determine the degree of actual and perceived agreement. Examining these differences also allows respondents to be categorized as being in one of four states (or contexts according to Leong, McComas, & Decker, 2007): (1) true consensus: when groups agree and know they agree, (2) true conflict: when groups disagree and know they disagree, (3) false consensus: when groups actually disagree but think they agree, and (4) false conflict: when groups actually agree but think they disagree (Figure 4.1).

Figure 4.1. Coorientation framework

		Actual Agreement	
		YES	**NO**
Perceived Agreement	**YES**	True Consensus	False Consensus
	NO	False Conflict	True Conflict

Methods

The coorientation framework described above was used to explore agency and community priorities, causes of muck, and impacts of muck. A modified version of coorientation was also used to investigate knowledge and beliefs about muck, community information sources, agency response, and management options. This approach required two versions of the online survey: one targeting agency representatives and the other targeting local citizens. In all cases respondents were asked to rate survey items on a 5-point scale. Each of the survey measures are described in more detail in the Results section below and samples of the agency and citizen surveys can be found in Appendices 4-B and 4-C.

In addition, the survey for agency representatives asked respondents to identify what agency or organization they represented. The citizen survey included demographic questions (e.g., age, gender, employment) as well as questions about place of residence, involvement in local organizations, and whether they owned property with beachfront access. Citizens were also asked to rate how frequently they visited the BCSRA in a typical year (*never to very often*) and whether they felt a strong personal connection to the recreation area (*strongly disagree to strongly agree*).

Survey Participants

Thirty-one (N=31) agency representatives completed the coorientation survey. Survey participants were identified with the help of staff from the Michigan Department of Natural Resources, Michigan Department of Environmental Quality, and Michigan Sea Grant. Once identified participants were sent a link to an online survey. These individuals were encouraged to share this link with other agency representatives familiar with the on-going beach muck problem in Saginaw Bay. Survey respondents were affiliated with a variety of agencies and organizations (see Table 4.2), including state resource management and environmental protection agencies (*n*=15), federal agencies focused on Great Lakes research (*n*=6), such as the National Oceanic and Atmospheric Administration, the Great Lakes Environmental Research Laboratory, and the U.S. Geological Survey, and federal agencies focused on regulation and environmental management (*n*=3), such as the U.S. Army Corps of Engineers. Respondents also included academic researchers studying the Great Lakes (*n*=4) and several unspecified natural agency representatives.

Table 4.2. Affiliations of agency representatives.

Michigan Department of Natural Resources (MDNR)	8
Michigan Department of Environmental Quality (MDEQ)	6
Academic Researcher	4
National Oceanic and Atmospheric Administration (NOAA) / Great Lakes Environmental Research Laboratory (GLERL) / Michigan Sea Grant	4
US Army Corps of Engineers	3
US Geological Survey (USGS)	2
Michigan Department of Agriculture & Rural Development (MDARD)	1
Not Specified	3
TOTAL	**31**

Table 4.3. Characteristics of citizen participants

Gender (%)	
Female	43.1
Male	56.9
Age (%)	
Under 29	8.6
30-39	13.2
40-49	15.7
50-59	25.1
60-69	26.0
70 or older	11.4
Employed (%)	
No	71.8
Yes	28.2
Own Beachfront Property (%)	
No	65.9
Yes	34.1
Bay City Residents (%)	
No	31.3
Yes	68.7
Involved in an organization concerned with muck (%)	
No	70.2
Yes	29.8
How often do you visit BCSRA (%)	
Never or Rarely	21.7
Sometimes	30.9
Often or Very Often	47.4
Personal connection to BCSRA (%)	
Strongly Disagree or Disagree	10.5
Not Sure	15.5
Strongly Agree or Agree	74.0

Six hundred and fifty (N=650) individuals completed the citizen version of the coorientation survey. A link to the online citizen survey was distributed via email to members of local environmental and property rights organizations, outdoor recreation and business groups, and individuals who had recently attended public meetings about park management issues. In addition, a link to the survey was included in two articles posted on a popular local online news site. This link was also posted on the BCSRA website and on flyers disturbed around the park itself. Citizen respondents tended to be male, between 50-69 years of age, employed, and residents of Bay City (see Table 4.3). The majority of citizen respondents indicated that they did not own beachfront property and visited the BCSRA at least occasionally. Just over one quarter of citizen participants indicated they were actively involved in a local organization concerned about the beach muck issue. Save Our Shoreline (SOS), a property rights group advocating for increased grooming of public and private beaches, was the most well represented local organization, with 95 responses coming from this group alone. Citizen respondents also indicated that they did feel some personal connection to the BCSRA.

Survey Analysis

In order to ensure construct validity and identify common themes, a factor analysis using principal component factoring with Varimax rotation was conducted using citizen responses about their personal attitudes and beliefs (as opposed to citizens' predictions of agency attitudes and beliefs) toward measures related to community priorities, causes of muck, impacts of muck, overall beliefs about muck, and agency response to muck. Factor structures were based on item loading of at least 0.50 and items loading on more than one factor were excluded. Alpha coefficients by and large indicated acceptable reliability (above 0.65). However, alpha levels for several factors were below 0.50 and should be interpreted with some caution. Results of this factor analysis, including individual item loadings, are detailed below.

Using R (R Core Team, 2015) and the package lme4 (Bates, Maechler & Bolker, 2012), a linear mixed effects analysis test was performed to detect differences in perceptions between the agency and citizen groups. For the fixed effect, a four-level group variable was used to differentiate agency, citizen, agency perceptions of citizens, and citizen perceptions of agencies. For the random effects, intercepts were entered for participants to account for within-subject correlations. Inspection of the residual plots did not reveal obvious deviations from homoscedasticity or normality. Model p-values were obtained using likelihood ratio tests of the full model with the effect in question against the model without the effect in question. When more than two groups were present, p-values for differences between the groups were obtained using the Tukey Post-hoc comparison using the lsmeans package (Lenth & Hervé, 2015). For single items, when within-subject correlations were not an issue, independent samples t-tests were used to test for significant differences. Similarly, for non-coorientation questions, comparisons were made using independent samples t-tests. Graphs were produced using the ggplot2 package (Wickham, 2009).

Results and Discussion

Community & Agency Priorities

Agency representatives and citizens were asked to rate 7 different issues related to natural resource preservation, outdoor recreation, and economic development (*not at all* to *extremely*) in terms of importance to the community and to agencies. Factor analysis of community priorities identified three distinct categories (see Table 4.4). The first category, *Tourism & Economy* was characterized by priorities that focused on increasing local tourism and economic activity. The *Beach Quality* category represented priorities that involved making improvements to the beachfront and rising property values of homes near Saginaw Bay. The third category, *Preserving Natural Resources* included priorities that focused on preserving natural habitat and improving water quality. The mixed effects test showed that the coorientation group variables significantly predicted changes in each of the factors—Tourism and Economy ($\chi2(3)=1140.5$, $p<0.0001$), Beach Quality ($\chi2(3)=838.18$, $p<0.0001$), and Preserving Natural Resources ($\chi2(3)=128.59$, $p<0.0001$). Table 4.5 and Figure 4.2 show the mean ratings and differences between the groups.

Citizens strongly endorsed all of the priorities measured, with each mean rating well above 4.00. When asked to assess agency priorities, citizens predicted agencies would rate lower levels of importance for each of the priorities, with *Beach Quality* receiving the lowest level of endorsement overall. Agency representatives placed high importance on *Preserving Natural Resources* and moderate importance on both *Tourism & Economy* and *Beach Quality*. When agency representatives were asked to predict community priorities, *Tourism & Economy* and *Beach Quality* were both perceived to be of higher importance to citizens than *Preserving Natural Resources*.

Table 4.4. Factor analysis categories of Community Priorities.

Category name and items included		Alpha
TOURISM & ECONOMY		.78
Items	*Loadings*	
Increasing local tourism	.93	
Increasing local economic activity	.90	
Outdoor recreation in and around Saginaw Bay	.54	
BEACH QUALITY		.49
Items	*Loadings*	
Improving the beachfront	.80	
Property values of homes near Saginaw Bay	.75	
PRESERVING NATURAL RESOURCES		.34
Items	*Loadings*	
Preserving local natural areas/habitat	.75	
Improving the water quality of Saginaw Bay	.73	

Table 4.5. Mean ratings and coorientation outcomes for Community & Agency Priorities

	CITIZENS	AGENCIES	CITIZEN VIEW OF AGENCIES	AGENCY VIEW OF CITIZENS
TOURISM & ECONOMY	4.44	3.59	3.13	4.43
BEACH QUALITY	4.35	3.13	2.67	4.58
PRESERVING NATURAL RESOURCES	4.36	4.37	3.89	3.37

	ACTUAL AGREEMENT†	CITIZENS' PERCEIVED AGREEMENT‡	AGENCIES' PERCEIVED AGREEMENT§	CITIZEN OUTCOME	AGENCY OUTCOME
TOURISM & ECONOMY	No (Diff=0.85, $p<0.0001$)	No (Diff=1.31, $p<0.0001$)	No (Diff=0.84, $p<0.0001$)	True Conflict	True Conflict
BEACH QUALITY	No (Diff=1.22, $p<0.0001$)	No (Diff=1.68, $p<0.0001$)	No (Diff=1.45, $p<0.0001$)	True Conflict	True Conflict
PRESERVING NATURAL RESOURCES	Yes (Diff=0.01, $p=1.000$)	No (Diff=0.47, $p<0.0001$)	No (Diff=1.004, $p<0.0001$)	False Conflict	False Conflict

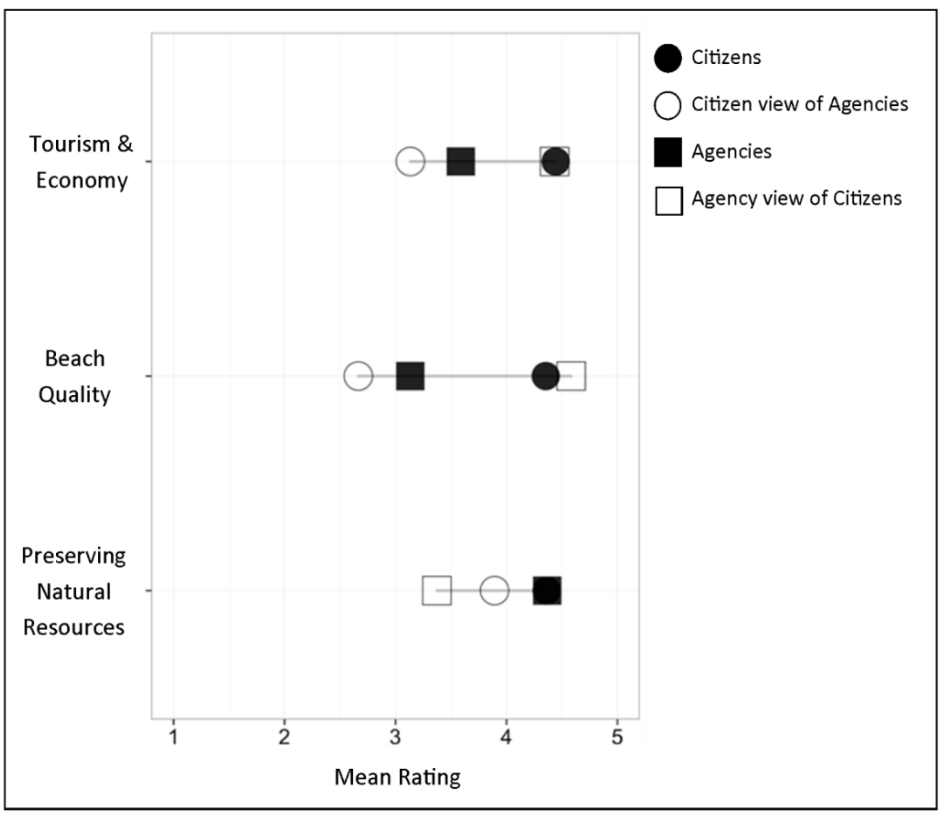
† Actual agreement is a lack of a statistical difference in group means between Citizens and Agencies

‡ Perceived agreement for citizens is a lack of a statistical difference in group means between Citizens and Citizen view of Agencies

§ Perceived agreement for agencies is a lack of a statistical difference in group means between Agencies and Agency view of Citizens

Applying the coorientation framework showed that agencies and citizens had two true conflicts and one false conflict. With respect to *Tourism & Economy*, mean ratings of importance differed significantly between the two groups. While each group accurately perceived this disagreement, indicating a true conflict on this issue, there was some evidence that agencies placed a greater priority on *Tourism & Economy* than citizens assume. Findings related to *Beach Quality* also indicated significant differences between groups, with citizens rating this as a much higher priority. Once again, both groups recognized this difference, suggesting another true conflict. It is noteworthy, however, that the small differences in means suggest only a minor conflict. Interestingly, citizen and agencies placed an equally high priority on *Preserving Natural Resources*. However, both groups significantly underestimated the ratings of one another, falling into the category of false conflict and thus offering the potential for common ground. This may be a surprise to the participants in that both groups perceive a conflict where none exists.

Figure 4.2. Comparison of community and agency priorities.



Knowledge of Beach Muck

Overall knowledge about muck was assessed by asking citizens to rate how much they knew about beach muck in Saginaw Bay (*nothing* to *a lot*). Agency representatives were asked to rate their own knowledge regarding beach muck on the same scale and to predict how much they felt the average citizen of Bay City knew about this issue.

Citizens indicated that they felt moderately knowledgeable about the muck issue, with a mean score slightly higher than mid-range (see Table 4.6). The mean knowledge rating of agency representatives was nearly half a point higher than that of citizens. While this difference was significant, it was not as substantial as agency representatives predicted. In fact, agencies significantly underestimated the knowledge that citizens felt they had regarding beach muck by more than a full rating point. Although this suggests that the public may be more educated than agencies realize, it is important to remember that citizen knowledge is likely to be quite varied, with some citizens knowing very little and others knowing a good deal more. This situation can create challenges for resource management agencies. Attempts to educate citizens about the basics of beach muck may be appropriate for some audiences, but citizens who feel more knowledgeable may not be interested or receptive to these kinds of efforts—wanting instead to discuss what they feel are more pressing issues, such as management actions.

Table 4.6. Mean ratings for Knowledge of Beach Muck

	CITIZENS	AGENCIES	AGENCY VIEW OF CITIZENS
KNOWLEDGE OF MUCK	3.49*	3.97*	2.43*

*all differences significant at $p<.001$ level using t-test

Information Sources about Beach Muck

In order to determine where the public turns for information about muck, citizens were asked to rate how frequently they rely on 8 different information sources (*never* to *very often*). Agency representatives were instead asked to predict how often local community members get information from these same sources. All survey respondents were then asked to briefly describe any other sources the public relies on to find out about beach muck.

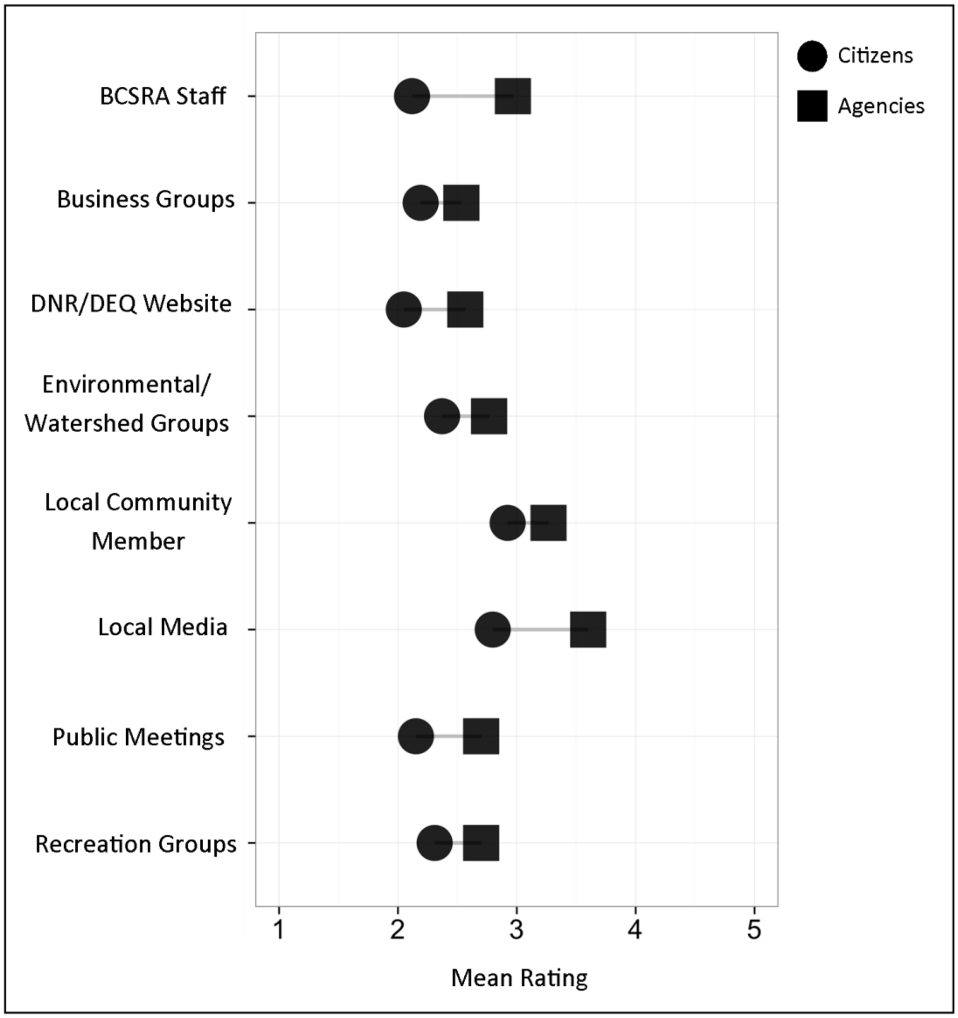
While local community members and local media were the most highly endorsed information sources among citizens, it is noteworthy that mean ratings of the various information sources never exceeded 3.00, indicating none were heavily relied upon (see Table 4.7 and Figure 4.3). When agency representatives were asked to predict the information sources of citizens several interesting patterns emerged. Agency representatives were able to correctly predict that local media and local community members would be the most relied upon sources of information; however they also tended to overestimate the importance of many information sources. In fact, agency representatives were only able to accurately predict the degree to which citizen relied upon one information source – business groups. Despite these misperceptions, agencies do seem aware of the fact that citizens are not heavily prioritizing any specific information source.

In open-ended responses, many citizens indicated that they got information about muck from their personal experience (76), meaning that they had directly observed muck on local beaches and/or at the BCSRA. These citizen-generated comments also highlighted several information sources mentioned above, including other community members (51) and local media (17). In addition, a number of citizen comments (24) specifically mentioned Save Our Shoreline (SOS) as an information source regarding muck-related issues.

Table 4.7. Mean ratings for Information Sources about Beach Muck

	CITIZENS	AGENCY VIEW OF CITIZENS	SIGNIFICANCE
BCSRA STAFF	2.12	2.97	Yes (Diff=0.85, p<.0001)
BUSINESS GROUPS	2.19	2.53	No (Diff=0.34, p=.0718)
DNR AND/OR DEQ WEBSITES	2.05	2.57	Yes (Diff=.52, p=.0003)
ENVIRONMENTAL/WATERSHED GROUPS	2.37	2.77	Yes (Diff=0.40, p=.0169)
LOCAL COMMUNITY MEMBERS	2.92	3.27	Yes (Diff=0.35, p=.0225)
LOCAL MEDIA	2.80	3.60	Yes (Diff=0.80, p<.0001)
PUBLIC MEETINGS	2.15	2.70	Yes (Diff=0.55, p=.0010)
RECREATION GROUPS	2.31	2.70	Yes (Diff=0.39, p=.0150)

Figure 4.3. Comparison of information sources about beach muck.



Causes of Beach Muck

Causes of muck were investigated by asking agency representatives and citizens to rate how much they felt 15 items contributed to the formation of beach muck (*not at all* to *extremely*). The coorientation approach was also used with respect to these questions, as citizen respondents were asked to make predictions of how much they felt agencies attributed muck formation to these issues and agency representatives were asked to make predictions about citizens. After rating these items, all respondents were given an opportunity to briefly describe any additional factors that contribute to muck formation and accumulation.

The factor analysis associated with causes of muck revealed three distinct categories (see Table 4.8). The first, *Ecosystem Factors* related to elements of the natural systems that contributed to muck formation. Some of these issues, such as water temperature and wind and wave action, concerned daily and seasonal fluctuations in the natural system. Other issues, such as invasive mussels and climate change, were associated with more recent alterations to the ecosystem. Overall, items included in this category involved natural forces that are not easily changed through human intervention. The second factor, *Nutrient Loading* attributed muck formation to the increase in phosphorus and nitrogen from non-point sources, such as residential and agricultural fertilizer application. Finally, *Wastewater* was composed of items more closely identified with point source pollution, such as waste discharges from residential septic systems and municipal sewage treatment facilities. Mixed effects testing showed significant differences between citizens and agencies for all three factors—Ecosystem Factors ($\chi2(3)=801.35$, $p<0.0001$), Nutrient Loading ($\chi2(3)=225.54$, $p<0.0001$), and Wastewater ($\chi2(3)=126$, $p<0.0001$). Table 4.9 and Figure 4.4 show the mean ratings and differences between the groups.

Citizens primarily attributed beach muck to *Nutrient Loading* and *Wastewater*. Citizens also identified *Ecosystem Factors* as contributing to the problem, but less so than other causes. When asked about how agencies saw causes, citizens predicted that agencies would highly endorse all three types of causes, giving mean predicted ratings all greater than 4.00. Agency representatives indicated that *Nutrient Loading* contributed most to muck, followed by *Ecosystems Factors* and *Wastewater*. Agency representatives were more conservative in their predictions of citizens with no cause receiving a mean rating higher than 4.00. Agencies also anticipated that citizens would primarily attribute muck to *Wastewater*.

Using the coorientation framework to explore the different ways citizens and agencies see the causes of muck can prove instructive. This data revealed that both groups placed a similar emphasis on *Ecosystem Factors* and *Nutrient Loading*, but citizens placed greater importance on *Wastewater*. Both groups believed they were in disagreement with respect to all of the causes mentioned. In the case of *Wastewater*, these perceptions were accurate suggesting a true conflict. However, these perceptions were not accurate with respect to both *Ecosystem Factors* and *Nutrient Loading*. In these two cases, citizens overestimated the beliefs of agencies while agency representatives underestimated the beliefs of citizens, suggesting both causes are a potential source of false conflict.

Table 4.8. Factor analysis categories related to Causes of Beach Muck

Category name and items included		**Alpha**
ECOSYSTEM FACTORS		.82
Items	*Loadings*	
Wind and wave action	.73	
Lower water levels in Saginaw Bay	.73	
Natural processes	.70	
Increased water clarity	.64	
Increased water temperature	.64	
Climate change	.57	
Invasive mussels	.54	
NUTRIENT LOADING		.83
Items	*Loadings*	
Increased phosphorus levels	.76	
Increased nitrogen levels	.76	
Fertilizer runoff from residential areas/businesses	.66	
Algae and aquatic plant growth	.66	
Fertilizer runoff from farming operations	.59	
WASTEWATER		.69
Items	*Loadings*	
Wastewater treatment failures/sewage overflows	.70	
Leaking septic systems	.68	
Water pollution	.68	

Table 4.9. Mean ratings and coorientation outcomes for Causes of Beach Muck

	CITIZENS (N=650)	AGENCIES (N=31)	CITIZEN VIEW OF AGENCIES (N=650)	AGENCY VIEW OF CITIZENS (N=31)
ECOSYSTEM FACTORS	3.37	3.54	4.37	3.02
NUTRIENT LOADING	4.17	4.11	4.64	3.49
WASTEWATER	3.99	3.20	4.46	3.86

	ACTUAL AGREEMENT†	CITIZENS' PERCEIVED AGREEMENT‡	AGENCIES' PERCEIVED AGREEMENT§	CITIZEN OUTCOME	AGENCY OUTCOME
ECOSYSTEM FACTORS	Yes (Diff=0.17, p=0.8613)	No (Diff=1.00, p<0.0001)	No (Diff=0.52, p=0.0006)	False Conflict	False Conflict
NUTRIENT LOADING	Yes (Diff=0.06, p=0.9893)	No (Diff=0.47, p<0.0001)	No (Diff=0.62, p<0.0001)	False Conflict	False Conflict
WASTEWATER	No (Diff=0.79, p=0.0012)	No (Diff=0.47, p<0.0001)	No (Diff=0.66, p=0.0019)	True Conflict	True Conflict

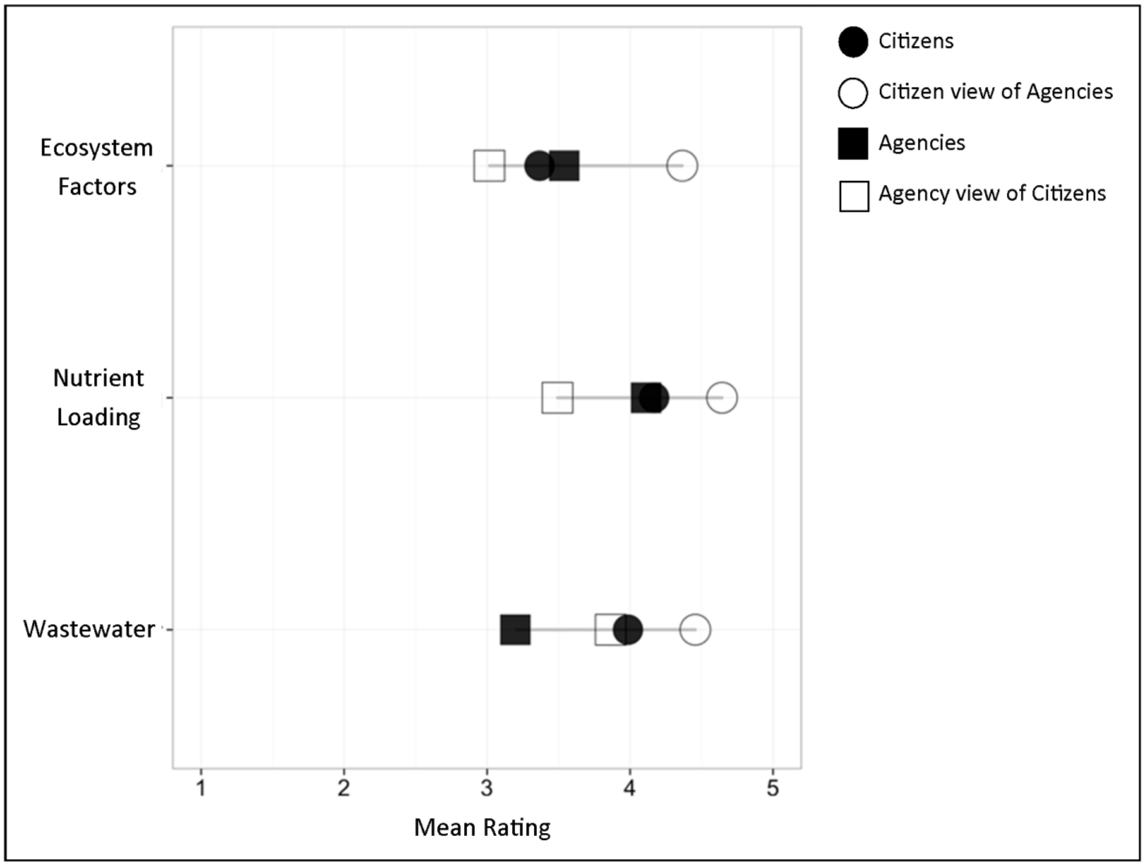
† Actual agreement is a lack of a statistical difference in group means between Citizens and Agencies

‡ Perceived agreement for citizens is a lack of a statistical difference in group means between Citizens and Citizen view of Agencies

§ Perceived agreement for agencies is a lack of a statistical difference in group means between Agencies and Agency view of Citizens

Many of the open-ended responses provided by citizens elaborated on causes related to the three categories identified above. However, nearly one quarter of citizen comments (52) suggested that man-made structures, specifically a barrier island built by the U.S. Army Corps of Engineers near the mouth of the Saginaw River, contributed to muck deposition at the BCSRA. There were also numerous citizen comments (23) indicating that the agencies themselves were responsible due to their unwillingness to clean muck from the beach. In total, these comments suggested that citizens blame this problem on a broader set of factors than those recognized by agencies.

Figure 4.4. Comparison of causes of beach muck.



Impacts of Beach Muck

Consequences of muck were assessed by asking agency representatives and citizens to rate how concerned they were about 9 different health, aesthetic, and economic outcomes (not at all to extremely). Once again a coorientation approach was used. Citizens were asked to rate how concerned they felt agencies were about these outcomes and agency representatives were asked to make predictions about the concerns of the local community members. All respondents were also asked to briefly describe any other outcomes that result from beach muck.

Three distinct categories emerged from the factor analysis related to impacts of beach muck (see Table 4.10). The first category, *Park Use & Local Economy* included items associated with the negative impact muck has on park attendance, tourism, and economic activity. The second factor generated, termed *Well-Being*, concerned health risks associated with muck contact on humans and wildlife and overall quality of life effects. One single item, *Bad odor/smell*, also emerged as salient, reflecting how the scent of decomposing organic material on the beach negatively impacts the aesthetic experience. The mixed effects test showed that citizens and agency representatives differed significantly on each of the factors—*Park Use & Local Economy* ($\chi2(3)=1050.1$, $p<0.0001$), *Well-Being* ($\chi2(3)=140.08$, $p<0.0001$), *Bad Odor/Smell* ($\chi2(3)=264.19.1$, $p<0.0001$). Mean ratings and coorientation outcomes are shown in Table 4.11 and Figure 4.5.

Citizens expressed high levels of concern with respect to all three categories of impacts, with each mean rating exceeding 4.20. However, citizens were more circumspect about the concerns of agencies, with only *Well-Being* receiving a mean rating above 3.50. Agency representatives were most concerned about *Bad Odor/Smell* followed by *Park Use & Local Economy*. It is worth noting, however, that none of these impacts received mean ratings above 4.00. When asked to predict citizens' concerns, agency representatives guessed that citizens would strongly endorse both *Bad Odor/Smell* and *Park Use & Local Economy*, while they would be less concerned about *Well-Being*.

Table 4.10. Factor analysis categories related to Impacts of Beach Muck

Category name and items included		**Alpha**
PARK USE & LOCAL ECONOMY		.91
Items	*Loadings*	
Reduced tourism	.92	
Reduced economic activity in Bay City	.86	
Lower rates of park attendance	.86	
Less enjoyment of the Bay City State Rec Area	.77	
WELL-BEING		.70
Items	*Loadings*	
Negative impacts on wildlife	.89	
Health risks	.77	
Lower quality of life	.61	
BAD ODOR/SMELL *(single item)*		--

Table 4.11. Mean ratings and coorientation outcomes for Impacts of Beach Muck

	CITIZENS	AGENCIES	CITIZEN VIEW OF AGENCIES	AGENCY VIEW OF CITIZENS
PARK USE & LOCAL ECONOMY	4.62	3.70	3.32	4.39
WELL-BEING	4.23	3.38	3.69	3.76
BAD ODOR/SMELL	4.71	3.96	3.24	4.88

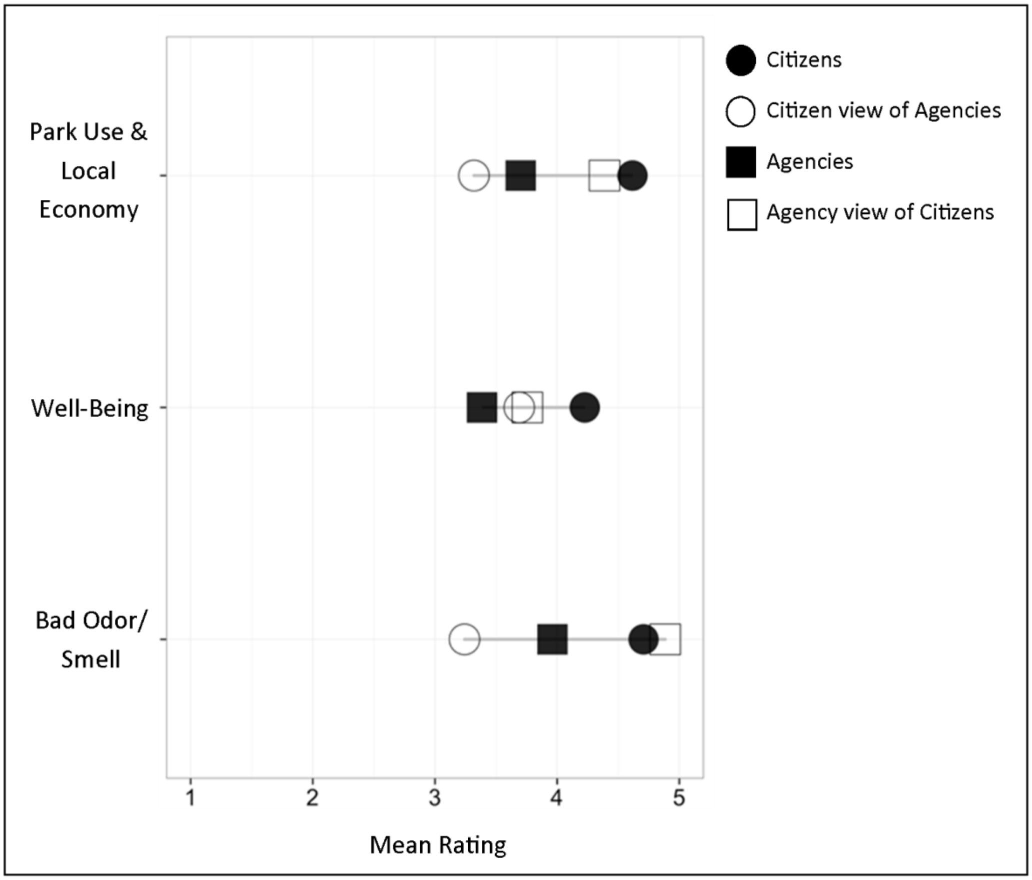
	ACTUAL AGREEMENT †	CITIZENS PERCEIVED AGREEMENT ‡	AGENCIES' PERCEIVED AGREEMENT §	CITIZEN OUTCOME	AGENCY OUTCOME
PARK USE & LOCAL ECONOMY	No (Diff=0.90, p<0.0001)	No (Diff=1.30, p<0.0001)	No (Diff=0.69, p<0.0001)	True Conflict	True Conflict
WELL-BEING	No (Diff=0.85, p=0.0001)	No (Diff=0.54, p<0.0001)	Yes (Diff=0.38, p=0.19)	True Conflict	False Consensus
BAD ODOR/ SMELL	No (Diff=0.75, p=0.02)	No (Diff=1.47, p<0.0001)	No (Diff=0.92, p=.04)	True Conflict	True Conflict

† Actual agreement is a lack of a statistical difference in group means between Citizens and Agencies
‡ Perceived agreement for citizens is a lack of a statistical difference in group means between Citizens and Citizen view of Agencies
§ Perceived agreement for agencies is a lack of a statistical difference in group means between Agencies and Agency view of Citizens

Once again, viewing differences between groups through the lens of coorientation can offer valuable insight. Across the board, citizens reported a higher level of concern about impacts than agencies. Mean ratings of both *Park Use & Local Economy* and *Bad Odor/Smell* differed significantly between the two groups. Although each group accurately perceived this difference, suggesting these are sources of true conflict, it also appears that citizens may underestimate the concern of agencies. The impacts on *Well-Being* are a noteworthy exception in that agency representatives mistakenly believed their level of concern aligned with citizens, when in fact they underestimated the concern citizens had for the issue. On the other hand, citizens accurately perceived this discrepancy resulting in a state of true conflict for citizens, but a state of false consensus for agencies.

Open-ended responses of citizens reinforced many of the impacts cited above, focusing on issues such as risks to human health (11), as well as reductions in beach use (22) and economic activity (18). Interestingly, a number of citizens mentioned that muck negatively impacted the reputation of the community (23) and contributed to feelings of tension and distrust between citizens and resource management agencies (17).

Figure 4.5. Comparison of impacts of beach muck.



Beliefs about Beach Muck

Overall beliefs regarding muck were explored by asking agency representatives and citizens to rate their level of agreement (strongly disagree to strongly agree) with 14 different statements about the nature of the problem and the importance of having a clean beach. For these particular questions, agency representatives and citizens were only asked about their own views, they were not asked to make predictions about one another.

Five separate categories were generated from the factor analysis examining beliefs about beach muck (see Table 4.12). *Value of a Clean Beach* emerged as the first category and focused on the importance of having a usable, muck-free beach. Several items included in this factor also emphasized the effect beach cleaning would have on park visitation and the local economy. Items that formed the *Persistence of Muck* category represented beliefs about whether muck formation and deposition is a long-standing and natural part of the Saginaw Bay ecosystem. The next category, *Need to Better Understand Muck* dealt with the uncertainty of muck levels over time and the need to study this phenomenon more closely. The *Cleaning is a Challenge* factor highlighted the financial costs associated with beach cleaning and the necessity of regular, on-going cleaning efforts. Finally, one single item, *Wetlands should be removed to expand the beach*, emerged as salient. The mixed effects analysis revealed that citizens and agency representatives differed significantly on four of the five factors—*Value of a Clean Beach* ($\chi2(1)=85.66$, $p<0.0001$), *Persistence of Muck* ($\chi2(1)=75.71$, $p<0.0001$), *Cleaning is a Challenge* ($\chi2(1)=8.03$, $p<0.0046$), and *Wetlands Should be Removed* ($t(31.34)=6.50$, $p<.0001$)—but not for the *Need to Better Understand Muck* ($\chi2(1)=0.00$, $p=0.995$) where agencies and citizens were in agreement.

Table 4.12. Factor analysis categories related to Beliefs about Beach Muck

Category name and items included		Alpha
VALUE OF A CLEAN BEACH		.78
Items	*Loadings*	
Having a clean beach will greatly increase use of the BCSRA	.81	
The community has a right to a clean beach at the BCSRA	.74	
Having a clean beach will revitalize the local economy	.72	
Beach muck is a serious problem at the BCSRA	.69	
PERSISTENCE OF MUCK		.64
Items	*Loadings*	
Beach muck is a natural part of Saginaw Bay	.72	
Beach muck has always been a problem at the BCSRA	.68	
The BCSRA has been muck free in the past and can be again (rev)	.65	
Despite management efforts, beach muck will never completely go away	.65	
NEED TO BETTER UNDERSTAND MUCK		.46
Items	*Loadings*	
Muck levels have changed in the past and will continue to change in the future	.78	
More research needs to be done on the causes of beach muck	.78	
CLEANING IS A CHALLENGE		.45
Items	*Loadings*	
Cleaning up beach muck will cost a lot of money	.79	
Cleaning up beach muck will require a sustained, long-term effort	.73	
WETLANDS SHOULD BE REMOVED TO EXPAND THE BEACH *(single item)*		--

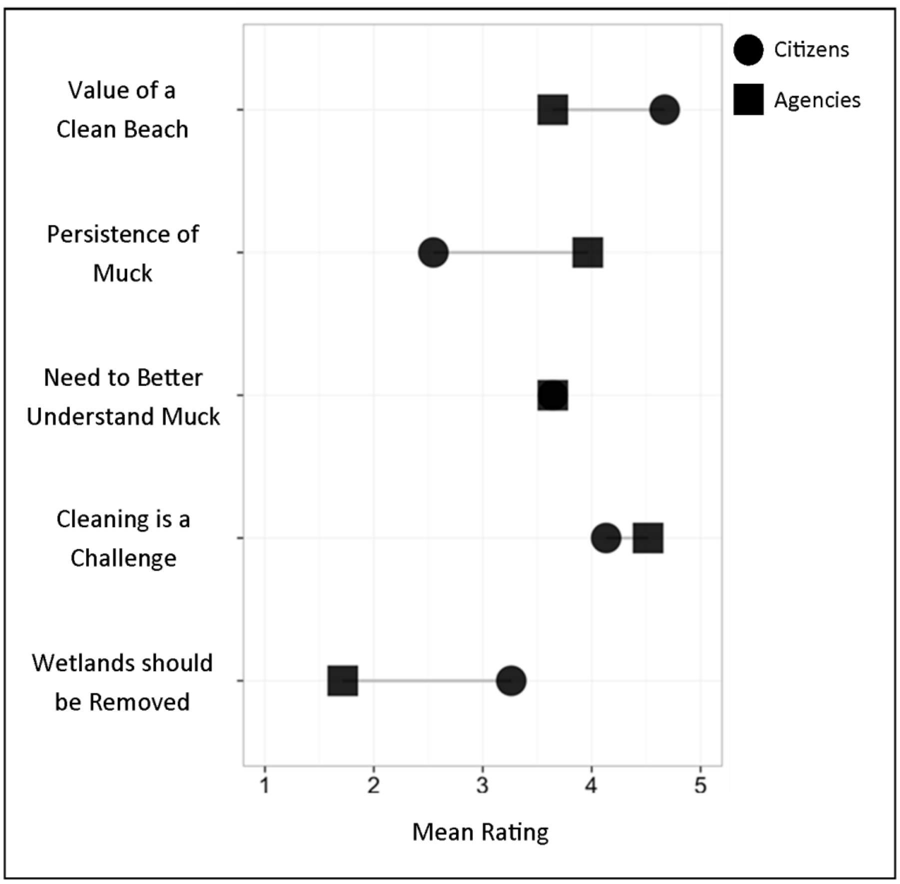
As seen in Table 4.13 and Figure 4.6, citizens expressed a strong endorsement for the *Value of a Clean Beach*, suggesting that locals see beach muck as a serious problem that not only negatively impacts use of the BCSRA but also hinders local economic activity. The mean ratings of agency representatives related to this same category showed a more modest level of endorsement with this view. In fact, scores of agency representatives were significantly lower than that that of citizens indicating more uncertainty on the part of agencies about the severity of muck and/or about whether a muck free beach would result in greater park visitation and increased economic opportunity. It is worth noting that a similar theme emerged with respect to the impacts associated with beach muck reported above. In this case citizens were also significantly more concerned about how muck impacted park use and the local economy than agency representatives. Citizens' strong endorsement of the *Cleaning is a Challenge* category suggests the public understands there is no cheap, easy solution to muck and that management efforts will likely require considerable investments of time and resources. This view is endorsed even more strongly by agency representatives, as indicated by the significant difference in mean scores. Despite this difference, it is encouraging that both groups appear to acknowledge management challenges. The *Need to Better Understand Muck* received similar levels of support from both citizens and agency representatives. The fact that citizens are somewhat supportive of efforts to better understand the factors that have contributed to muck may be slightly surprising given that some community members have been critical of agency supported research efforts – seeing them as an excuse to further delay management action.

Citizen responses about whether *Wetlands Should be Removed* suggested there was uncertainty about this action, with mean scores only slightly above 3.00. Given the mandates of many resource management agencies, it may not be surprising that agency representatives were strongly opposed to this action. Although it is important to keep in mind that citizens were fairly uncertain about wetland removal, this issue did generate substantial disagreement between the two groups. As a result, agencies may need to more clearly communicate the ecological, recreational, and economic benefits associated with wetlands protection and discuss the idea, held by some citizens, that wetland preservation and restoration is somehow linked to beach muck. The final category, *Persistence of Muck,* also generated significant disagreement between citizens and agency representatives. Citizen ratings were well below mid-scale, indicating skepticism among local community members about whether muck has always been a natural part of Saginaw Bay. Agency representatives, on the other hand, were much more likely to see muck as a normal and natural phenomenon.

Table 4.13. Mean ratings for Beliefs about Beach Muck

	CITIZENS (N=650)	AGENCIES (N=31)	SIGNIFICANT DIFFERENCE
VALUE OF A CLEAN BEACH	4.67	3.64	Yes (Diff=1.03, p<.001)
PERSISTENCE OF MUCK	2.55	3.96	Yes (Diff=1.41, p<.001)
NEED TO BETTER UNDERSTAND MUCK	3.64	3.64	No (Diff=0.00, p=1.00)
CLEANING IS A CHALLENGE	4.13	4.52	Yes (Diff=0.39, p=.005)
WETLANDS SHOULD BE REMOVED	3.26	1.71	Yes (Diff=1.55, p<.001)

Figure 4.6. Comparison of beliefs about beach muck.



Agency Response to Beach Muck

Agency response was investigated by asking citizens to rate their level of agreement (strongly disagree to strongly agree) with 15 different statements about agency efforts to understand muck, manage the problem, and work with local community. Agency representatives, on the other hand, were asked to make predictions about how citizens would response to these same statements.

Factor analysis of items related to agency response revealed five distinct and coherent categories (see Table 4.14). The first of these, *Community Outreach & Engagement*, reflected agency efforts to actively involve the community, understand citizen concerns, and treat citizens fairly. The next category, *Action on Muck* included items associated with whether appropriate agency personal were involved and overall agency efforts to address the problem. The third factor, *Increasing Park Attendance* emphasized agencies' desire to increase park use and improve local economic conditions. *Caring about Muck* emerged as the fourth category and was composed of items related to whether agencies empathize with the community and have a commitment to clean up muck. The last factor, *Knowledge of Muck* related to agencies' understanding of the causes and solutions to muck formation and deposition. Mixed effects test showed that agencies predictions of citizens perception of their efforts were fairly accurate for four of the five factors-- *Action on Muck* ($\chi2(1)=2.88$, $p=0.0896$), *Increasing Park Attendance* ($\chi2(1)=2.72$, $p=0.0991$), *Caring about Muck* ($\chi2(1)=0.10$, $p=0.7567$), *Agency Knowledge of Muck* ($\chi2(1)=1.96$, $p=0.1614$)—but less accurate for *Community Outreach & Engagement* ($\chi2(1)=3.97$, $p=0.0463$).

Table 4.14. Factor analysis categories related to Agency Response to Beach Muck

Category name and items included		**Alpha**
COMMUNITY OUTREACH & ENGAGEMENT		.91
Items	*Loadings*	
Agencies try to actively engage the community about park management issues	.84	
Agencies communicate effectively with the public	.81	
Agencies understand concerns of the local community	.72	
Agencies treat community members fairly	.70	
Agencies have made improvement to the BCSRA overall	.67	
Agencies have tried to improve the beachfront at the BCSRA	.58	
ACTION ON MUCK		.86
Items	*Loadings*	
Agencies have the right people working on the muck problem	.83	
Agencies are making a reasonable effort to try and address beach muck	.70	
Agencies are trying to provide the public with useful information about muck	.56	
INCREASING PARK ATTENDANCE		.81
Items	*Loadings*	
Agencies want to attract more people to the BCSRA	.80	
Agencies want to improve the local economy	.69	
CARING ABOUT MUCK		.62
Items	*Loadings*	
Agencies don't care about the feelings of the community (rev)	.85	
Agencies are not interested in cleaning up beach muck (rev)	.80	
AGENCY KNOWLEDGE OF MUCK		.57
Items	*Loadings*	
Agencies know what is causing beach muck	.89	
Agencies know what to do about beach muck	.70	

The data presented in Table 4.15 and Figure 4.7, suggests that citizens were somewhat unsatisfied with the efforts of resource management agencies. *Action on Muck* and *Community Outreach & Engagement* received the lowest mean ratings among the citizen sample, indicating a desire to see agencies take more aggressive action and be more responsive to community concerns. Citizens were also fairly doubtful about *Agency Knowledge of Muck*, with the low mean rating reflecting a lack of confidence in agencies' understanding about the causes of muck and potential strategies for addressing this problem. As similar trend is evident with respect to *Increasing Park Attendance*, with citizens expressing some skepticism about whether agencies are committed to attracting more park visitors and taking steps to improve local economic conditions. The final category, *Caring about Muck*, received a neutral rating from citizen respondents, suggesting uncertainty about whether agencies were concerned about community feelings and serious about addressing beach muck.

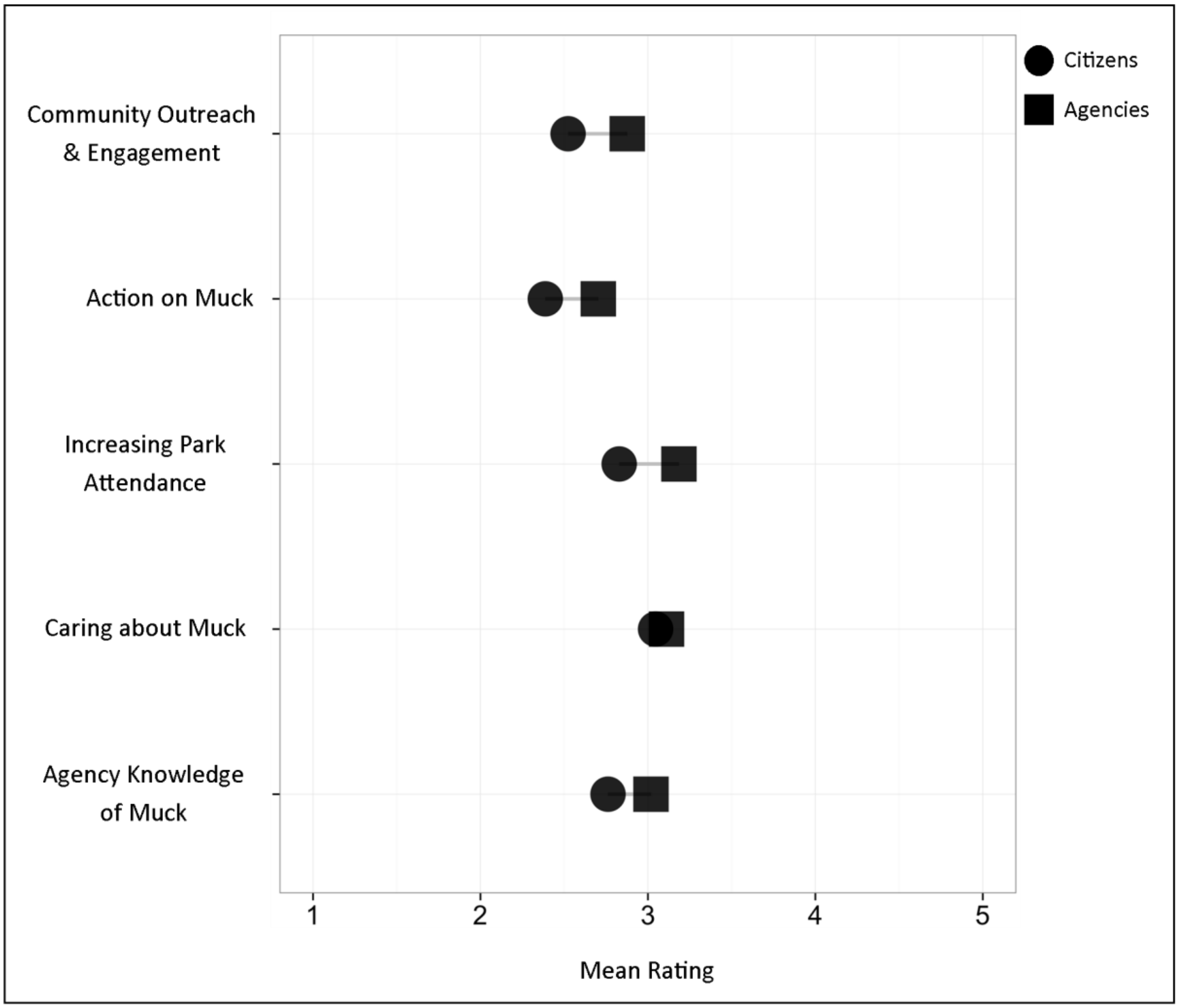
Although agency representatives were able to predict citizen feelings about most agency response categories with a fair degree of accuracy, representatives did tend to slightly overestimate citizens' satisfaction. This issue was most obvious with respect to *Community Outreach and Engagement*, where a significant difference emerged between citizen responses and agency predictions. Overall, this pattern seems to suggest that, while agencies are aware of community frustrations, they can sometimes underestimate the strength of these feelings.

Table 4.15. Mean ratings for agency response to beach muck.

	CITIZENS (N=650)	AGENCY VIEW OF CITIZENS (N=31)	SIGNIFICANT DIFFERENCE
COMMUNITY OUTREACH & ENGAGEMENT	2.52	2.88	Yes (Diff=.36, p=.046)
ACTION ON MUCK	2.38	2.70	No (Diff=.32, p=.095)
INCREASING PARK ATTENDANCE	2.83	3.19	No (Diff=.36, p=1.00)
CARING ABOUT MUCK	3.05	3.11	No (Diff=.06, p=1.00)
AGENCY KNOWLEDGE OF MUCK	2.76	3.02	No (Diff=.26, p=.757)

The most prevalent view expressed by citizens in open-ended responses concerned the belief that agencies do not care about the muck problem and/or are unwilling to take management action (44). Some citizens also suggested that political pressure or disagreement among agencies may be interfering with management efforts (16). Other comments offered more specific recommendations to agencies, such as focusing less on wetland protection (19), taking more aggressive action to reduce nutrient loading (i.e., regulating farming practices; 18), increasing beach cleaning efforts (15), and working more closely with local organizations (12). Interestingly, a number of comments were more sympathetic to agencies, acknowledged that the issue is very difficult to solve (16), agency funding and resources are limited (8), and relationships between agencies and citizens have actually improved in recent years (3). A few citizens also stated that there is a need to better understand the problem (7) and explore other solutions (7).

Figure 4.7. Comparison of agency response to beach muck.



Management Options

In order to assess management options, agency representatives and citizens were asked to rate 10 strategies (not at all to extremely). Respondents first rated each strategy in terms of its effectiveness at reducing beach muck and then were ask to rate the same strategy in terms of how practical it would be to implement. Citizens respondents were also asked to briefly describe any other strategies that they would like agencies to implement.

According to Table 4.16 and Figure 4.8, citizens evaluated all management options as being at least somewhat effective and practical; with mean ratings for every option well above 3.00. That said the use of a *Muck Filtering Machine* and *Physical Removal* of muck from the beach were deemed as the two most effective management options by citizens. *Removal of Aquatic Plants/Algae*, *Regulation of Agricultural Runoff*, and *Dredging of Swimming Areas* were also judged to be fairly effective strategies, with mean ratings at or slightly above 4.00. Citizens seemed to make less significant distinctions about whether certain management options were more practical than others. While strategies such as *Physical Removal* and *Regulation of Agricultural Runoff* did receive the highest mean ratings, no single strategy appeared to stand out as being most practical for citizens.

Agency representatives were much more critical of the effectiveness and practicality of all the proposed management strategies; with only one strategy, *Physical Removal*, receiving a mean rating above 3.00 for both effectiveness and practicality. Other strategies, such as *Regulation of Agricultural Runoff*, *Removal of Aquatic Plants*, *Permanent Barriers*, and *Removable Barriers* were all deemed to be moderately effective by agency representatives, but received lower endorsements with respect to practicality.

Table 4.16. Mean ratings about the effectiveness and practicality of management options

	CITIZEN EFFECTIVENESS (N=650)	CITIZEN PRACTICALITY (N=650)	AGENCY EFFECTIVENESS (N=31)	AGENCY PRACTICALITY (N=31)
RELAXED WETLAND REGULATIONS	3.85	3.67	1.85	2.08
FLOATING DOCKS	3.34	3.46	2.16	2.60
MUCK FILTERING MACHINE	4.29	3.72	2.88	2.12
INSTALLATION OF PIER/BOARDWALK	3.46	3.46	2.31	2.24
DREDGING OF SWIMMING AREAS	4.00	3.69	2.00	1.68
REMOVAL OF AQUATIC PLANTS/ALGAE	4.05	3.67	3.32	1.92
REGULATION OF AG RUNOFF	4.03	3.83	3.35	2.92
PERMANENT BARRIERS	3.68	3.29	3.31	2.40
REMOVABLE BARRIERS	3.82	3.50	3.23	2.76
PHYSICAL REMOVAL/GROOMING	4.24	3.95	3.54	3.04

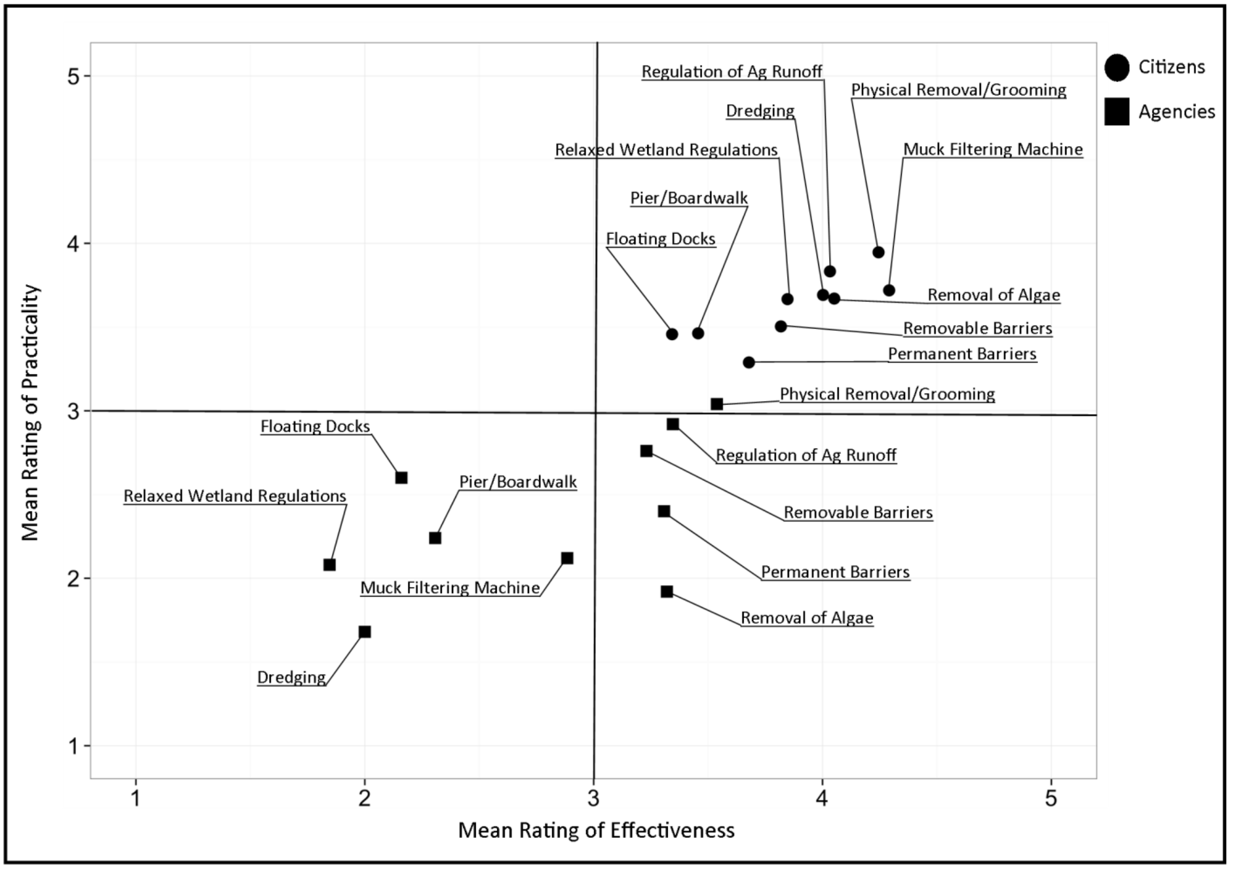
Results comparing citizen and agency representative ratings of effectiveness and practicality for each management option show many significant differences (Table 4.17). The most substantial differences emerged with respect to *Relaxed Wetlands Regulation*, *Dredging of Swimming Areas*, *Muck Filtering Machine*, and *Installation of Pier/Boardwalk*; citizen and agency evaluations of both effectiveness and practicality differed by well over a full rating scale point. *Removal of Aquatic Plants* was judged relatively positively in terms of effectiveness by both groups, but was deemed as one of the least practical strategies by agency representatives. There was slightly less disagreement about the remaining options. Permanent Barriers and Removable Barriers were judged to be similarly effective and practical by citizens and agency representatives. While *Physical Removal* and *Regulation of Agricultural Runoff* were the two strategies evaluated most positively by both citizens and agency representatives, some evidence suggest agency representatives felt both strategies would be less effective and practical than citizens believed.

Table 4.17. Mean differences between citizen and agency evaluations about the effectiveness and practicality of management options

	Citizen effectiveness Vs Citizen practicality	Agency effectiveness Vs Agency practicality	Citizen effectivness Vs Agency effectiveness	Citizen practicality Vs Agency practicality
Relaxed wetland regulations	Diff=.18, p=.031	Diff=-.23, p=.885	Diff=2.00, p<.001	Diff=1.59, p=.001
Floating docks	Diff=-.12, p=.386	Diff=-.44, p=.541	Diff=1.18, p=.007	Diff=.86, p=.073
Muck filtering machine	Diff=.57, p<.001	Diff=.68, p=.060	Diff=1.41, p<.001	Diff=1.60, p>.001
Installation of pier/boardwalk	Diff=0.00, p=1.00	Diff=.07, p=1.00	Diff=1.15, p=.007	Diff=1.22, p=.009
Dredging of swimming areas	Diff=.31, p<.001	Diff=.32, p=.391	Diff=2.00, p<.001	Diff=2.01, p<.001
Removal of aquatic plants/algae	Diff=38, p<.001	Diff=1.40, p<.001	Diff=.73, p=.136	Diff=1.75, p<.001
Regulation of ag runoff	Diff=.20, p=.006	Diff=.43, p=.301	Diff=.68, p=.061	Diff=.91, p=.006
Permanent barriers	Diff=.39, p<.001	Diff=.91, p=.012	Diff=.37, p=.745	Diff=.89, p=.105
Removable barriers	Diff=.32, p<.001	Diff=.47, p=.182	Diff=.59, p=.267	Diff=.74, p=1.00
Physical removal/grooming	Diff=.29, p<.001	Diff=.50, p=.091	Diff=.70, p=.015	Diff=.91, p=.001

In open-ended responses, citizen comments emphasized many strategies previously included on the survey, with management options related to addressing the underlying causes of muck formation (i.e., nutrient loading; 23) and increasing beach grooming (21) receiving the highest level of endorsement. This may suggest that citizens are thinking of only a limited number of management solutions and/or that they are relatively committed to a specific set of management solutions. Given that agencies are skeptical of many of the current proposed options, and citizens are proposing few alternative solutions, more creative thinking about management options – by both parties – may be necessary.

Figure 4.8. Comparison of citizen and agency evaluations of effectiveness and practicality of management options.



Conclusion

The challenge presented by muck accumulations on the shores of Saginaw Bay is a multidisciplinary problem. While a great deal of resources have been devoted by management agencies to researching the scientific causes and consequences of muck, fewer resources have been utilized to understand the perceptions and concerns of the public. This research has studied citizen perceptions and attitudes about the causes, impacts, and solutions to the muck challenge. Additionally, it has compared citizens perceptions to that of agency representatives, identifying areas of agreement and disagreement. Understanding these areas can help agencies better direct their public engagement strategies to find solutions that are amenable to both sides and reduce the tensions that are present currently. Some disagreements are a result of misperceptions—that is one party may believe the other to have a different point of view when both parties are actually in agreement. In these cases, correcting these misperceptions can lead to common ground. More challenging are the areas in which true conflicts exist. Here, parties must be willing to actively listen to and build empathy for each other's perspectives. Doing so may be aided by building on areas of agreement and framing the issues so that they can be worked on using participatory problem solving approaches. This study thus provides a first step towards addressing the negative impacts beach muck has had on the people in Saginaw Bay, in particular the animosity between the agencies and citizens who care most deeply about the issue.

References

Austin, D. E. (1994). *Exploring perceptions of hazardous waste facility proposals in Indian country: an application of the active symbol cognitive map model*. Ann Arbor, MI: University of Michigan.

Barton, D. R., E. T. Howell, and C. L. Fietsch. (2013). Ecosystem changes and nuisance benthic algae on the southeast shores of Lake Huron. *Journal of Great Lakes Research*, 39(4), 602-611.

Byappanahalli, M. N., D. A. Shively, M. B. Nevers, M. J. Sadowsky, and R. L. Whitman. (2003). Growth and survival of Escherichia coli and enterococci populations in the macro-alga Cladophora (Chlorophyta). *FEMS Microbiology Ecology*, 46(2), 203-211.

Byrch, C., Kearins, K., Milne, M., & Morgan, R. (2007). Sustainable "what"? A cognitive approach to understanding sustainable development. *Qualitative Research in Accounting & Management*, 4(1), 26-52.

Carrozzino-Lyon, A. L., S. L. McMullin, and J. A. Parkhurst. (2014). Coorientation of State Wildlife Agency Personnel and Wildlife Management Area Stakeholders Regarding Wildlife Habitat Management Activities in Virginia. *Environmental Communication*, 8(4), 508-528.

Connelly, N. A. and B. A. Knuth. (2002). Using the coorientation model to compare community leaders' and local residents' views about Hudson river ecosystem restoration. *Society & Natural Resources*, 15(10), 933-948.

Harris, V. (2004). Cladophora confounds coastal communities: Public perceptions and management dilemmas. In H. Bootsma, E. Jensen, E. Young, & J. Berges (Eds.), *Cladophora research and management in the Great Lakes* (pp. 5-14). University of Wisconsin-Milwaukee: The Great Lakes WATER Institute. http://www.seagrant.wisc.edu/home/Portals/0/Files/Water%20Quality/Dec_05_Cladophora_Research_Workshop_Proceedings_2.pdf

Higgins, S. N., S. Y. Malkin, E. T. Howell, S. J. Guildford, L. Campbell, V. Hiriart-Baer, and R. E. Hecky. (2008). An ecological review of Cladophora glomerata (Chlorophyta) in the Laurentian great lakes. *Journal of Phycology*, 44(4), 839-854.

Kearney, A. R., & Kaplan, S. (1997). Toward a methodology for the measurement of knowledge structures of ordinary people the conceptual content cognitive map (3CM). *Environment and Behavior*, 29(5), 579-617.

Kearney, A. R., Bradley, G., Kaplan, R.,& Kaplan, S. (1995). Stakeholder perspectives on appropriate forest management in the Pacific Northwest. *Forest Science*, 45(1), 62–73.

Kearney, A. R. (2015). 3CM: A tool for knowing "where they're at". In R. Kaplan & A. Basu (Eds.) *Fostering reasonableness: Supportive environments for bringing out our best*. Ann Arbor, MI: Michigan Publishing.

Lenth, R. V. and M. Hervé. (2015). *lsmeans: Least-Squares Means*. R package version 2.18. http://CRAN.R-project.org/package=lsmeans

Leong, K. M., K. A. McComas, and D. J. Decker. (2007). Matching the Forum to the Fuss: Using Coorientation Contexts to Address the Paradox of Public Participation in Natural Resource Management. *Environmental Practice*, 9(03), 195-205.

Leong, K. M., K. A. McComas, and D. J. Decker. (2008). Formative coorientation research: A tool to assist with environmental decision making. *Environmental Communication*, 2(3), 257-273.

McLeod, J. M. and S. H. Chaffee. (1973). Interpersonal approaches to communication research. *American Behavioral Scientist*, 16(4), 469-499.

National Oceanic & Atmospheric Administration. (2013). *Saginaw Bay Multiple Stressors Summary Report* (NOAA Technical Report No. TM-160). http://www.glerl.noaa.gov/ftp/publications/tech_reports/glerl-160/tm-160.pdf

Newcomb, T. M. (1953). An approach to the study of communicative acts. *Psychological Review*, 60(6), 393.

R Core Team. (2015). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Twight, B. W. and J. J. Paterson. (1979). Conflict and public involvement: measuring consensus. *Journal of Forestry*, 77(12), 771-776.

Verhougstraete, M. P., M. N. Byappanahalli, J. B. Rose, and R. L. Whitman. (2010). Cladophora in the Great Lakes: Impacts on beach water quality and human health. *Water Science & Technology*, 62(1), 68-76.

Wickham, H. (2009). *ggplot2: elegant graphics for data analysis*. Springer: New York.

Winslow, K. P., S. N. Francoeur, and S. D. Peacor. (2014). The influence of light and nutrients on benthic filamentous algal growth: a case study of Saginaw Bay, Lake Huron. *Journal of Great Lakes Research*, 40, 64-74.

Appendix 4-A: 3CM Pre-Generated Responses

agricultural run-off/fertilizer	fertilizer application	sewage treatment overflows
nutrient loading	leaking septic systems	cost/feasibility of removal
invasive mussels	water clarity	water temperature
climate change	wind and wave action	aquatic plants, algae
harm to native species/wildlife	economic impacts	impacts on tourism
recreation	beach use	bad odor/foul smell
health concerns	change in quality of life	frustration among local residents
DNR/DEQ response to muck	outreach/communication efforts	public meetings
scientific research on muck	wetlands protection	park management
preservation of natural resources	beach grooming	physical removal of muck
disposal of muck	working with other communities	education about the bay
stricter regulations (regarding run-off/fertilizer application)	physical barriers to prevent muck from accumulating	nearby land management practices
commercial pier	lack of clear solutions	muck filtering machine/device
dredging of the bay	pristine beachfront	nitrogen levels
phosphorus levels	boat wastewater	water pollution
increase of muck overtime	a new problem	complexity of problem

Appendix 4-B: Agency Representative Survey

EX

Thank you for participating in this study. The purpose of this survey is to explore how natural resource agencies, researchers, and community leaders view beach muck. The survey asks you to share your views and to make some predictions about how the local community views this issue. Please answer these questions as completely and honestly as possible. We want to assure you that the answers you provide will not be used in any that violates your privacy.

1. In what capacity have you been involved in the beach muck issue (check all that apply)?
   - ☐ Michigan DNR
   - ☐ Michigan DEQ
   - ☐ Academic researcher
   - ☐ Local government official
   - ☐ NOAA/Michigan Sea Grant/GLERL
   - ☐ Local watershed or environmental organization
   - ☐ Other (please specify): ___________________________________

2. How much do you know about beach muck in Saginaw Bay?
   ☐ Nothing ☐ A little ☐ Some ☐ A good deal ☐ A lot

3. How much do you think the average Bay City citizen knows beach muck in Saginaw Bay?
   ☐ Nothing ☐ A little ☐ Some ☐ A good deal ☐ A lot

4. Please rate the following issues in terms of:
   A. How important each issue is to the local community; AND
   B. How important each issue is to agencies, such as the DNR and DEQ?

1 = not at all	2 = slightly	3 = somewhat	4 = very	5 = extremely

A. How important to the community?		B. How important to agencies?
1 2 3 4 5	Preserving local natural areas/habitats	1 2 3 4 5
1 2 3 4 5	Increasing local tourism	1 2 3 4 5
1 2 3 4 5	Improving the water quality of Saginaw Bay	1 2 3 4 5
1 2 3 4 5	Increasing local economic activity	1 2 3 4 5
1 2 3 4 5	Outdoor recreation in and around Saginaw Bay	1 2 3 4 5
1 2 3 4 5	Improving the beachfront	1 2 3 4 5
1 2 3 4 5	Property values of homes near Saginaw Bay	1 2 3 4 5

5. How often do you think the local community gets information about muck from the following sources?

1 = never	2 = rarely	3 = sometimes	4 = often	5 = very often

1 2 3 4 5	Local media
1 2 3 4 5	Local community members
1 2 3 4 5	DNR and/or DEQ websites
1 2 3 4 5	Bay City State Recreation Area staff
1 2 3 4 5	Recreation groups
1 2 3 4 5	Public meetings
1 2 3 4 5	Environmental and/or watershed management groups
1 2 3 4 5	Business groups (e.g., Chamber of Commerce, Tourism Board, etc.)

Briefly describe any other sources you think the public relies on to find out about beach muck?

EX

6. Please indicate how much you agree with the following statements.

1 = strongly disagree	2 = disagree	3 = not sure	4 = agree	5 = strongly agree

1	2	3	4	5	The community has a strong personal connection to the Bay City State Rec Area.
1	2	3	4	5	Beach muck is a serious problem at the Bay City State Rec Area.
1	2	3	4	5	Beach muck has always been a problem in Saginaw Bay.
1	2	3	4	5	The accumulation of beach muck has increased during the last 5-10 years.
1	2	3	4	5	Beach muck is a natural part of Saginaw Bay.
1	2	3	4	5	The community has a right to a clean beach at the Bay City State Rec Area.
1	2	3	4	5	Having a clean beach will greatly increase use of the Bay City State Rec Area.
1	2	3	4	5	Cleaning up beach muck will require a sustained, long-term effort.
1	2	3	4	5	Cleaning up beach muck will cost a lot of money.
1	2	3	4	5	Having a clean beach will revitalize the local economy.
1	2	3	4	5	Wetlands should be removed to expand the beach at the Bay City State Rec Area.
1	2	3	4	5	More research needs to be done on the causes of beach muck.
1	2	3	4	5	Muck levels have changed in the past and will continue to change in the future.
1	2	3	4	5	Despite management efforts, beach muck will never completely go away.
1	2	3	4	5	The Bay City State Rec Area has been muck free in the past and can be again.

7. Please rate each of the following for:
   A. How much do local community members think each causes beach muck; AND
   B. How much do agencies, such as the DNR and DEQ, think each causes beach muck?

1 = not at all	2 = slightly	3 = somewhat	4 = a lot	5 = extremely	X = don't know

A. What does the community think causes muck?							B. What do agencies think causes muck?					
1	2	3	4	5	X	Fertilizer runoff from farming operations	1	2	3	4	5	X
1	2	3	4	5	X	Water pollution	1	2	3	4	5	X
1	2	3	4	5	X	Invasive mussels	1	2	3	4	5	X
1	2	3	4	5	X	Lower water levels in Saginaw Bay	1	2	3	4	5	X
1	2	3	4	5	X	Increased water clarity	1	2	3	4	5	X
1	2	3	4	5	X	Wind and wave action	1	2	3	4	5	X
1	2	3	4	5	X	Natural processes	1	2	3	4	5	X
1	2	3	4	5	X	Leaking septic systems	1	2	3	4	5	X
1	2	3	4	5	X	Increased water temperature	1	2	3	4	5	X
1	2	3	4	5	X	Wastewater treatment failures/sewage overflows	1	2	3	4	5	X
1	2	3	4	5	X	Climate change	1	2	3	4	5	X
1	2	3	4	5	X	Increased phosphorus levels	1	2	3	4	5	X
1	2	3	4	5	X	Fertilizer runoff from residential areas/businesses	1	2	3	4	5	X
1	2	3	4	5	X	Algae and aquatic plant growth	1	2	3	4	5	X
1	2	3	4	5	X	Increased nitrogen levels	1	2	3	4	5	X

Briefly describe any other factors that cause beach muck?

8. Below is a list of outcomes that may be associated with beach muck. Please rate each in terms of:
   A. How much it concerns the <u>local community</u>; AND
   B. How much it concerns <u>agencies</u>, such as the DNR and DEQ?

1 = not at all	2 = slightly	3 = somewhat	4 = a lot	5 = extremely	X = don't know

A. How concerned is the community?		B. How concerned are agencies?
1 2 3 4 5 X	Health risks	1 2 3 4 5 X
1 2 3 4 5 X	Negative impacts on wildlife	1 2 3 4 5 X
1 2 3 4 5 X	Lower quality of life	1 2 3 4 5 X
1 2 3 4 5 X	Lower rates of park attendance	1 2 3 4 5 X
1 2 3 4 5 X	Bad odor/smell	1 2 3 4 5 X
1 2 3 4 5 X	Reduced tourism	1 2 3 4 5 X
1 2 3 4 5 X	Less enjoyment of the Bay City State Rec Area	1 2 3 4 5 X
1 2 3 4 5 X	Reduced economic activity in Bay City	1 2 3 4 5 X
1 2 3 4 5 X	Less attractive beach	1 2 3 4 5 X

Briefly describe any other outcomes that might result from beach muck?

9. Please indicate how much you agree with the following statements about <u>how the public feels about</u> the efforts of natural resource management agencies, such as the Michigan DNR and DEQ.

1 = strongly disagree	2 = disagree	3 = not sure	4 = agree	5 = strongly agree

	The local community believes that agencies…
1 2 3 4 5	…know what is causing beach muck.
1 2 3 4 5	…want to attract more people to the Bay City State Recreation Area.
1 2 3 4 5	…are trying to provide the public with useful information about muck.
1 2 3 4 5	…are making a reasonable effort to try and address beach muck.
1 2 3 4 5	…have the right people working on the muck problem.
1 2 3 4 5	…have tried to improve the beachfront at the Bay City State Recreation Area.
1 2 3 4 5	…have made improvements to the Bay City State Recreation Area overall.
1 2 3 4 5	…understand concerns of the local community.
1 2 3 4 5	…try to actively engage the community about park management issues.
1 2 3 4 5	…communicate effectively with the public.
1 2 3 4 5	…treat community members fairly.
1 2 3 4 5	…know what to do about beach muck.
1 2 3 4 5	…don't care about the feelings of the community.
1 2 3 4 5	…want to improve the local economy.
1 2 3 4 5	…are not interested in removing beach muck.

10. Please rate the following muck management strategies in terms of the following:
    A. How <u>effective</u> you think each would be at reducing beach muck; AND
    B. How <u>practical</u> you think each would be to implement?

1 = not at all	2 = slightly	3 = somewhat	4 = a lot	5 = extremely	X = don't know

A. How effective?		B. How practical?
1 2 3 4 5 X	Regular physical removal (i.e., beach grooming)	1 2 3 4 5 X
1 2 3 4 5 X	Removable barriers to prevent muck accumulation on the beach (i.e., nets, booms)	1 2 3 4 5 X
1 2 3 4 5 X	Permanent barriers to prevent muck accumulation on the beach (i.e., rock/concrete seawall)	1 2 3 4 5 X
1 2 3 4 5 X	Greater regulation of agricultural runoff	1 2 3 4 5 X
1 2 3 4 5 X	Removal of aquatic plants, algae	1 2 3 4 5 X
1 2 3 4 5 X	Dredging of swimming areas	1 2 3 4 5 X
1 2 3 4 5 X	Installation of a pier or boardwalk	1 2 3 4 5 X
1 2 3 4 5 X	Muck filtering machine	1 2 3 4 5 X
1 2 3 4 5 X	Floating docks	1 2 3 4 5 X
1 2 3 4 5 X	Relaxed wetland protection regulations	1 2 3 4 5 X

Briefly describe muck management strategies you think citizens would like agencies to implement.

11. Do you have any additional comments?

THANK YOU FOR YOUR TIME!

Appendix 4-C: Citizen Survey

NEX

Thank you for participating in this study. This survey gives you an opportunity to share your views about beach muck in Saginaw Bay and about how agencies, such as the Dept. of Natural Resources (DNR) and Dept. of Environmental Quality (DEQ), are addressing this issue. We want to assure you that the answers you provide will not be used in any that violates your privacy.

1. Do you live in Bay City?
   ☐ No ☐ Yes → If yes, how long have you lived in Bay City? ___________________

2. Are you involved in any local organizations that deal with the Bay City State Rec Area?
   ☐ No ☐ Yes → If yes, please list:____

3. Do you own beachfront property or property with beach access?
   ☐ No ☐ Yes

4. Please rate the following issues in terms of:
   A. How important each issue is to you; AND
   B. How important each issue is to agencies, such as the DNR and DEQ?

1 = not at all	2 = slightly	3 = somewhat	4 = very	5 = extremely

A. How important is this to you?		B. How important is this to agencies?
1 2 3 4 5	Preserving local natural areas/habitats	1 2 3 4 5
1 2 3 4 5	Increasing local tourism	1 2 3 4 5
1 2 3 4 5	Improving the water quality of Saginaw Bay	1 2 3 4 5
1 2 3 4 5	Increasing local economic activity	1 2 3 4 5
1 2 3 4 5	Outdoor recreation in and around Saginaw Bay	1 2 3 4 5
1 2 3 4 5	Improving the beachfront	1 2 3 4 5
1 2 3 4 5	Property values of homes near Saginaw Bay	1 2 3 4 5

5. How frequently do you visit the Bay City State Recreation Area during a typical year?
   ☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Very Often

6. How much do you think you know about beach muck in Saginaw Bay?
   ☐ Nothing ☐ A little ☐ Some ☐ A good deal ☐ A lot

7. How often do you get information about beach muck from the following sources?

1 = never	2 = rarely	3 = sometimes	4 = often	5 = very often

1 2 3 4 5	Local media
1 2 3 4 5	Local community members
1 2 3 4 5	DNR and/or DEQ websites
1 2 3 4 5	Bay City State Recreation Area staff
1 2 3 4 5	Recreation groups
1 2 3 4 5	Public meetings
1 2 3 4 5	Environmental and/or watershed management groups
1 2 3 4 5	Business groups (e.g., Chamber of Commerce, Tourism Board, etc.)

Briefly describe any other sources you rely on to find out about beach muck?

8. Please indicate how much you agree with the following statements.

1 = strongly disagree	2 = disagree	3 = not sure	4 = agree	5 = strongly agree

1	2	3	4	5	I feel a strong personal connection to the Bay City State Rec Area.
1	2	3	4	5	Beach muck is a serious problem at the Bay City State Rec Area.
1	2	3	4	5	Beach muck has always been a problem in Saginaw Bay.
1	2	3	4	5	The accumulation of beach muck has increased during the last 5-10 years.
1	2	3	4	5	Beach muck is a natural part of Saginaw Bay.
1	2	3	4	5	The community has a right to a clean beach at the Bay City State Rec Area.
1	2	3	4	5	Having a clean beach will greatly increase use of the Bay City State Rec Area.
1	2	3	4	5	Cleaning up beach muck will require a sustained, long-term effort.
1	2	3	4	5	Cleaning up beach muck will cost a lot of money.
1	2	3	4	5	Having a clean beach will revitalize the local economy.
1	2	3	4	5	Wetlands should be removed to expand the beach at the Bay City State Rec Area.
1	2	3	4	5	More research needs to be done on the causes of muck.
1	2	3	4	5	Muck levels have changed in the past and will continue to change in the future.
1	2	3	4	5	Despite management efforts, beach muck will never completely go away.
1	2	3	4	5	The Bay City State Rec Area has been muck free in the past and can be again.

9. Please rate each of the following for:
   A. How much you think each causes beach muck; AND
   B. How much agencies, such as the DNR and DEQ, think each causes beach muck?

1 = not at all	2 = slightly	3 = somewhat	4 = a lot	5 = extremely	X = don't know

A. How much do you think this causes muck?							B. How much do agencies think this causes muck?					
1	2	3	4	5	X	Fertilizer runoff from farming operations	1	2	3	4	5	X
1	2	3	4	5	X	Water pollution	1	2	3	4	5	X
1	2	3	4	5	X	Invasive mussels	1	2	3	4	5	X
1	2	3	4	5	X	Lower water levels in Saginaw Bay	1	2	3	4	5	X
1	2	3	4	5	X	Increased water clarity	1	2	3	4	5	X
1	2	3	4	5	X	Wind and wave action	1	2	3	4	5	X
1	2	3	4	5	X	Natural processes	1	2	3	4	5	X
1	2	3	4	5	X	Leaking septic systems	1	2	3	4	5	X
1	2	3	4	5	X	Increased water temperature	1	2	3	4	5	X
1	2	3	4	5	X	Wastewater treatment failures/sewage overflows	1	2	3	4	5	X
1	2	3	4	5	X	Climate change	1	2	3	4	5	X
1	2	3	4	5	X	Increased phosphorus levels	1	2	3	4	5	X
1	2	3	4	5	X	Fertilizer runoff from residential areas/businesses	1	2	3	4	5	X
1	2	3	4	5	X	Algae and aquatic plant growth	1	2	3	4	5	X
1	2	3	4	5	X	Increased nitrogen levels	1	2	3	4	5	X

Briefly describe any other factors that you think may cause beach muck?

12. Please rate the following muck management strategies in terms of the following:
    A. How effective do you think each would be at managing beach muck; AND
    B. Given limited agency resources, how practical do you think each would be to implement?

1 = not at all	2 = slightly	3 = somewhat	4 = a lot	5 = extremely	X = don't know

A. How effective?							B. How practical?					
1	2	3	4	5	X	Regular physical removal (i.e., beach grooming)	1	2	3	4	5	X
1	2	3	4	5	X	Removable barriers to prevent muck accumulation on the beach (i.e., nets, booms)	1	2	3	4	5	X
1	2	3	4	5	X	Permanent barriers to prevent muck accumulation on the beach (i.e., rock/concrete seawall)	1	2	3	4	5	X
1	2	3	4	5	X	Greater regulation of agricultural runoff	1	2	3	4	5	X
1	2	3	4	5	X	Removal of aquatic plants, algae	1	2	3	4	5	X
1	2	3	4	5	X	Dredging of swimming areas	1	2	3	4	5	X
1	2	3	4	5	X	Installation of a pier or boardwalk	1	2	3	4	5	X
1	2	3	4	5	X	Muck filtering machine	1	2	3	4	5	X
1	2	3	4	5	X	Floating docks	1	2	3	4	5	X
1	2	3	4	5	X	Relaxed wetland protection regulations	1	2	3	4	5	X

Briefly describe any other muck management strategies you would like agencies to implement.

13. Gender: ☐ Male ☐ Female

14. Age: ☐ Under 18 ☐ 18-29 ☐ 30-39 ☐ 40-49 ☐ 50-59 ☐ 60-69 ☐ 70-79 ☐ 80 or older

15. Are you currently employed?
    ☐ No → If no, what is your status (retired, unemployed, full-time parent, etc.): ____________________

    ☐ Yes → If yes, briefly describe your line of work:____

16. Do you have any additional comments?

THANK YOU FOR YOUR TIME!

Chapter 5: Management Solutions to muck at BCSRA

To complement work presented in the preceding chapters on environmental modeling, public perception surveys and economic analysis, this IA project concluded by further exploring the feasibility of existing and potential management considerations (e.g., muck removal options and their ease of implementation and relative success) and assess the costs associated with those options. This occurred through an integrated, stakeholder-driven process that built upon efforts by Bay County and the MDNR to explore and assess options to enhance visitation to the park, with a focus on the Saginaw Bay shoreline. This chapter presents current management efforts around the Great Lakes basin, then focuses on the outcomes of the workshops held as part of this IA to better understand near and long-term sustainable recreation and maintenance recommendations for the muck issue. This information will also be valuable for evaluating management action as it relates to the AOC's Aesthetics BUI restoration criteria development.

Management of shoreline muck in the Great Lakes basin

Factors affecting shoreline deposition in the Great Lakes

Abiotic factors are nonliving components of the environment that effect resident species and influence ecosystem function. Some examples of abiotic factors include wind effects, lake and watershed topography, temperature, water pH, light penetration/attenuation, and oxygen concentrations. Abiotic factors dramatically influence natural processes in Great Lakes ecosystems. Although the five Great Lakes are connected, abiotic factors act as filters for biota which influence community composition and contribute to each lake's unique ecology.

Since each of the Great Lakes feature unique abiotic conditions which contribute to shoreline deposition patterns, shoreline debris varies in quantity and composition among the Great Lakes. Beach muck, which is largely comprised of macrophytes and algae, is a feature of more productive, eutrophic lakes such as Lake Erie, and parts of Lakes Michigan and Huron, including Saginaw Bay. Beaches in less productive, oligotrophic Great Lakes such as Lake Michigan, Huron, and Superior are typically fouled by zebra mussel shells and woody debris. This variation in shoreline deposition leads park managers to implement a variety of grooming techniques and management strategies. As part of this IA, we contacted personnel responsible for over 70 Great Lakes beaches to gather details on debris management strategies and cost (Table 5.1).

Overview of debris management strategies

Great Lakes state park managers have used many management options to maintain beach aesthetics in the region (management options discussed further in Section 2). Management techniques can be as simple and affordable as hand raking and as complex and expensive as mechanical removal. At minimum, most park managers utilize park employees to hand rake swim beaches on an as needed basis. The hand raking process consists of manually raking fouled beach areas with a strong, reinforced garden rake and physically removing raked contents from affected areas. As such, hand raking can be a cheap and easy way to manage shoreline deposition. However, there are times when hand raking cannot sufficiently manage shoreline deposition, and more extreme measures are taken.

Mechanical removal often entails the implementation of heavy machinery to groom beaches by screening, sifting or raking sand. Machinery utilized for these tasks can present as stand-alone tractors, tow-behind landscape rakes and more. The most expensive and effective of these methods are stand-alone tractors. These large machines require storage, routine maintenance, registration, and operator licensure. Since beach cleaners and screeners can be expensive and cumbersome to manage, many districts have elected to split the investment and share the device while others have excluded beach cleaners from management plans. A more modest investment are landscape rakes. Landscape rakes are towed behind a tractor, grooming the beach as the tractor advances. These devices are less expensive than beach cleaning machines and are widely implemented among Great Lakes beaches.

Beach management practices in Great Lakes beaches

Lake Huron

With a total surface area of 60,000 km^2 and total volume of 3,500 km^3, Lake Huron is the second largest Great Lake. Lake Huron is over 330 km long, 300 km wide and contacts 13 counties in Michigan and Ontario, Canada. Lake Huron shoreline deposition rates and composition vary with wind patterns, water levels and geomorphology. Due to its size and variation in deposition, park managers at Lake Huron public beaches employ a variety of strategies to manage beach fouling debris.

We have interviewed 15 park managers across eight of the thirteen Michigan counties that Lake Huron contacts directly regarding beach management practices (Table 5.1). We did not, however, speak with Canadian park management authorities concerning swim beach management. This confines our contacted beaches to the west side of Lake Huron.

Of the 15 beaches contacted, 14 were entirely sandy swim beaches and even the outlying rocky beach at Lakeport State Park had sandy areas. The composition of shoreline deposition amongst the Lake Huron beaches ranged from woody debris to black muck, but seemed to be similar between counties and regions. This is expected because shoreline deposition is governed by productivity, underwater currents, wave action and wind effects. Since most counties are geographically small, swim beaches contained within should be subject to similar patterns and subsequent beach fouling deposits.

The county that may be subject to the most severe beach fouling in Lake Huron, outside of Bay County, is Huron County. Huron County is a top producing agricultural county in Michigan, which could lead to increased non-point, phosphorus runoff. However, Huron County is large and crosses four watersheds. This confines the consequences of land use activity in Lake Huron to outlet areas in the lake and results in a variety of beach fouling issues in Huron county beaches.

In large part, shoreline deposition in Huron County consists of litter and woody debris. This is the case in Harbor Beach, the three-mile beach Port Austin, and a small 900-foot beach in Caseville. Management in these beaches consists of typical raking strategies such as hand and landscape raking. The range of grooming frequencies at the beaches are conducted from a three hour a week commitment at Port Austin to an “as needed” basis at the others. At these beaches, the cost is negligible and was simply described as “low” since beach raking is performed by park employees who earn between $8-9 per hour as well as volunteer groups. In a Huron county beach located in Caseville, there are issues with highly decomposed, black muck washing ashore. Maintenance at this beach requires the use of a beach cleaning machine as well as manual removal. These beach management practices are typically performed prior to busy weekends and fecal coliform testing is performed weekly.

Tawas Point State Park in Iosco County, which contacts the northwest side of Saginaw Bay, experiences high levels of shoreline deposition after weather events. The composition of beach deposits at Tawas Point State Park consists largely of woody debris and litter. After storm events, and at times of high winds or wave action, Tawas Point employs the use of a beach cleaning machine which is owned and operated by a volunteer group, the Friends of Tawas Point. Otherwise, park staff manually removes woody debris from the shoreline daily. Since volunteer groups and park staff are responsible for beach maintenance, beach maintenance costs are low.

The swimming beaches at Harrisville and Negwegon state parks (Alcona county) are proximal to one another and share similar shoreline deposition patters. Shoreline deposition at these sites is composed largely of muck, pollen, mussel shells and woody debris. Although there is a variety of debris deposited at these two beaches, park managers maintain them using hand and landscape raking methods. Equipment is shared between the two beaches and each pays an employee $8.50 an hour for approximately two hours per week to maintain the swim beach. The major difference between these two beaches is that Harrisville performs weekly fecal coliform testing, while Negwegon does not.

There were also similarities in beach management practices in state parks located in Sanilac county, just south of Saginaw Bay. The two parks contacted in this study, Forester State Park and Sanilac County Park #4, have sandy beaches and similar beach deposition patterns. Beach deposition at these two parks consists largely of litter and woody debris which is managed by hand and landscape raking between one and two hours per week. Both beaches pay employees for management. Sanilac County Park #4 pays an employee $8.50 per hour while Forester State Park uses a ranger to care for the beach paying $20 an hour. This disparity in pay may be because the Sanilac county park stays clean on its own, and maintenance efforts at Forester State Park are centered around maintaining a natural beach environment.

South of Sanilac, St. Clair county has the only rocky beach contacted in Lake Huron. Lakeport State Park has a 1-mile shoreline that is both rocky and sandy in parts, but lacks a distinct swim beach. Beach deposition at Lakeport State Park consists mainly of woody debris which is removed by park staff manually each day. The remaining two Lake Huron Parks contacted are PM Hoeft State Park in Presque Isle county, and Cheboygan State Park in Cheboygan county. These counties are the northernmost counties in the Lake Huron basin. Both PM Hoeft and Cheboygan State parks are self-cleaning and require no beach maintenance from park staff.

Lake Michigan

With a surface are of 58,000 km^2, Lake Michigan is slightly smaller than Lake Huron. However, in terms of volume and depth, Lake Michigan has a larger volume and average/maximum depths of 85 m and 245 m (compared to Lake Huron which has a depth of 59 m on average and 282 m at its deepest point). With these morphological differences and entirely different wind and weather patterns, there are distinct differences in shoreline deposition between Lakes Huron and Michigan.

Lake Michigan also differs from Lake Huron in that it is in contact with four states; Michigan, Wisconsin, Illinois, and Indiana. Although Lake Michigan beaches are regulated under the same federal protections, there are likely subtle difference in regulations on the state level. Fifteen Lake Michigan beaches were contacted across all four states that comprise its shoreline, three in Wisconsin, ten in Michigan, one in Illinois and one in Indiana. Since the focus of this project is to understand the nature of beach management in Michigan beaches, data is heavily weighted to Lake Michigan beaches within the state of Michigan.

Michigan

Beach usage varies amongst Lake Michigan parks along the state of Michigan's coastline. Some parks, such as Leelanau State Park in Leelanau and Orchard Beach State Park in Manistee county, do not invest in the maintenance at their beaches. This is largely because these park beaches are kept as natural, scenic beaches and are not designated for swimming. However, this does not describe all beaches within those counties. For instance, PJ Hoffmaster State Park in Manistee county has three miles of sandy shoreline and features a maintained swim beach. Shoreline deposition at this beach consists of litter and algae and is highly maintained. This beach is hand raked daily and employs the usage of Cherrington and Barber beach cleaners. PJ Hoffmaster State Park has collaborated with the Nature Center and camping funds are used to maintain beaches. Beach maintenance is conducted 20 hours a week by park employees making $8.50 an hour.

Saugatuck State Park, located in Allegan county, is in the southern reaches of Lake Michigan. Beach deposition in this area consists of industrial waste (glass, metal, rebar, etc.), litter and dead animals washed ashore. Park managers spend approximately 20 hours a week removing debris using hand raking, landscape raking and a sand fence. Saugatuck has made major investments to maintain its beaches. The initial investment for their beach combing tractor was $30,000 and fuel and maintenance averages $20-40 a day. Additionally, park managers invest $100-200 a week in labor and $300 per year to set up and break down their sand fence.

There are some beach deposition patterns that emerge when coastline counties in Lake Michigan are broken into groups. Oceana, Muskegon, and Ottawa counties share a similar location along the eastern coast of Lake Michigan. Three beaches contacted in these counties; Silver Lake State Park in Oceana county, Marantha Resort in Muskegon, and Holland State Park in Ottawa, all show algae and woody debris washing ashore. As such, beach maintenance practices find common ground between the beaches. All three beaches use hand and landscape rakes; however, Holland State Park employs the use of a Barber beach sweeper as well. This sweeper, which is a recent purchase, cost the park $15,000 and they spend an additional $8000 a year purchasing and moving sand to the beach.

Just north of Oceana county, is Mason county and Ludington State Park. Like many beaches in Lake Michigan, Ludington State Park's shoreline deposition consists of litter and woody debris. Park managers control shoreline deposition by hand raking and towing a landscape rake behind a tractor. Hand raking is performed daily and the landscape rake is used on an as needed basis. Beach maintenance is performed by employees, and a snow fence is installed each fall which costs $500 a year. There is an addition $3000 spent yearly moving sand to the beach.

Much like the Lake Huron Beaches found in the Michigan's northern lower peninsula, Lake Michigan's northern beaches need little or no maintenance. Leelanau State Park in Leelanau county and Traverse City State Park in Grand Traverse county do not maintain their beaches. Since Leelanau State Park does not have a swim beach and maintains a scenic hiking trail along its beaches, it does not conduct routine beach maintenance. Traverse City State Park is self-cleaned by creek flows.

The only Lake Michigan state park contacted in the Upper Peninsula of Michigan along Lake Michigan is JW Wells State Park in Menominee county. Park managers describe this state park's shoreline deposition pattern as simply woody debris. This debris is managed via hand raking which is performed daily and costs between $20-25 per week. It has been mentioned that there is algae at this beach as well, but wave action removes this algae before it contacts the shore.

Wisconsin

The west side of Lake Michigan borders the state of Wisconsin. To assess maintenance techniques employed in Lake Michigan's Wisconsin beaches, we contacted three state parks in three counties; Wisconsin Office of the Great Lakes in Racine county, Kohler-Andrae State Park in Sheboygan county and Peninsula State Park in Door county. The southernmost county, Racine, is situated between Kenosha and Milwaukee counties. Due to industrial development, the southern counties in Wisconsin are the most populated counties in the state and Racine county has some of the most affected beaches.

The Wisconsin Office of the Great Lakes, located in Racine, Wisconsin, has done tremendous work to assess sources of nutrients that have been moved into the lake. This work has included identifying sources, and epigenetic research to understand algal dynamics. Beach deposition in Racine consists largely of algae and mussel shells which is managed by park employees and the city of Madison/Racine parks department. Management methods include the use of a beach curtain to block algae, use of a beach groomer and hand raking. Beach curtains are donated and maintained by the city of Madison; hand/landscape raking is performed by park employees and volunteers.

Further north along the Lake Michigan coastline is Sheboygan county where Kohler-Andrae State Park is located. Shoreline deposition at Kohler-Andrae State Park consists largely of algae, fish, mussel shells and litter. Although there is a variety of debris deposited upon the shoreline, the rate of deposition is low and largely maintained by Lake Michigan's own wave action. Thus, park managers can maintain swim beached through hand raking four times a week by a paid employee.

The northernmost Lake Michigan state park contacted in Wisconsin is Peninsula State Park in Door county. In 2016, since the lake levels are so high, Peninsula State Park beach is nearly underwater. In past years, shoreline deposition was comprised mainly of algae and was maintained using a beach grooming tractor as needed. Fecal coliform testing is still performed weekly at this park.

Indiana and Illinois

The southernmost point of Lake Michigan contacts the states of Indiana and Illinois. Compared to Michigan and Wisconsin, there are not many Lake Michigan beaches in Illinois and Indiana, and those present are subject to northern Indiana and Chicago area land use. Since Lake Michigan beaches are less common in Indiana and Illinois, data was available for only two beaches in this area: Moraine Hills State Park in Illinois and The National Lakeshore in Indiana.

Moraine Hills State park is in McHenry IL, in McHenry county and The Indiana National Lakeshore is centered in Porter, IN in Porter county. Since these two beaches are in a similar place on Lake Michigan, shoreline deposition is similar between beaches. Shoreline deposition at Moraine Hill and the Indiana National Lakeshore mainly consists of litter and woody debris. Moraine Hills State Park renovated their beach in 2015, thus beach maintenance practices are currently being established. The Indiana National Lakeshore has nearly 15 miles of shoreline and is maintained by park managers daily using beach grooming tractors. Management of this shoreline requires two to four park employees dedicating six hours a day to beach grooming.

Lake Erie

Compared to other Great Lakes, Lake Erie is small and shallow. With an average depth of 19 m, it is the shallowest of the Great Lakes. In recent times, Lake Erie has experienced harmful algal blooms that have led to temporary drinking water restrictions in northern Ohio. It is also known that when algal blooms die off, they decompose and wash ashore as beach fouling muck. To assess management of shoreline deposition in Lake Erie parks, eight parks were contacted, seven in Ohio and one in Pennsylvania.

Three of the Ohio parks are Cleveland metro parks and are managed by park staff employed by the city (Edgewater Beach, Dog Beach and Wendy Beach). These three sandy beaches feature similar shoreline deposition which is approximated to be 70% woody debris, 20% trash, 5% leaf litter and 5% macrophytes. These three beaches are maintained with a Cherrington beach cleaner and John Deere tractor that are employee operated and shared among the beaches. The purchase of these items was facilitated by the Northeast Ohio Regional Sewer District: $54,000 for the Cherrington beach cleaner and $89,000 for the John Deere tractor. Maintenance is conducted 60 hours per week for a total of 1,520 man hours per season. Fecal coliform testing is performed after rainfall events.

Just east of Cleveland is Lake county, which includes Headlands State Park. Headlands State Park is subject to the deposition of debris on its beaches during the entire recreational season and heavy deposition of algae in the spring. Spring algal depositions can total up to 300 cubic yards and are removed by heavy machinery. Employees remove debris from the beach four days a week, which is supported by the park operations budget.

Kelleys Island, South Bass Island and Battery Park are in Erie county. Two of these parks, Kelleys and South Bass islands have small swim beaches which are subject to deposition of woody debris and dead fish washing ashore. This debris is removed daily via hand and landscape raking and fecal coliform testing is performed weekly. Kelleys Island features a small 100 ft beach which is maintained by park staff. This is, however, different from South Bass Island which houses five full time residents to maintain all park functions. The beach at Battery Park is for hiking and scenic usage. As such, this beach is not maintained.

Presque Isle State Park is in Erie, PA. This park is situated on a 3,200-acre peninsula jutting in to Lake Erie, and provides Pennsylvania with 11 miles of sandy coastline. Beach deposition in Presque Isle is comprised mainly of algae with some woody debris. Beaches in this park are groomed with rakes, tractors and manual removal by employees and partner organizations such as the Regional Science Consortium which advises and monitors Presque Isle beaches.

Lake Superior

Lake Superior, the largest of the Great Lakes, has a surface area over 81, 200 km^2, making it the second largest freshwater lake in the world by surface area. The average depth of Lake Superior is 147 m with a maximum depth of 406 m which is significantly deeper than the other Great Lakes. Since Lake Superior is so large, deep, and cool, it has few problems with algae which limits beach deposition to woody debris. However, some beaches have reported muck deposition.

Brimley State Park, located in Chippewa county on the east side of Michigan’s Upper Peninsula has a ¼ mile sandy swim beach. This area is weather sensitive and is subject to shoreline deposition consisting of trees and woody debris, but occasionally experiences beach fouling via black muck. Most beach maintenance is conducted manually through cut and removal of woody debris. When black muck appears on the beach, tractors are used to remove and relocate beach fouling muck. However, this is infrequent and maintenance at this beach has been described as low. Park employees earning $8.50 per hour perform much of the maintenance and fecal coliform testing is performed weekly.

One of the most famous parks in Michigan is Pictured Rocks National Lakeshore. This state park is located at Munising, MI in Algers county in the north central Upper Peninsula. The Pictured Rocks National Lakeshore has 40 miles of coastline and varies between rocky and sandy coastline. Shoreline deposition is variable, but consists mainly of woody debris and fish. The state invests $30,000 per year to maintain this lakeshore using park employees. Pictured Rocks National Lakeshore has its own laboratory dedicated to fecal coliform testing.

Table 5.1. Current management practices for plant and other debris in the Great Lakes, by lake. Cells left blank where data not available.

Lake	Beach/Park	Location (state/province)	Shoreline treated	Beach	Deposition material	Grooming methods	Grooming frequency	Cost (annual[1])
Ontario								
	Fair Haven Beach	Fair Haven (NY)	975 m	Sandy	Stone, cobbles, garbage, 1 week of algae/summer	Surf rake with tractor	Daily	30,000
	Sand Banks Provincial Park	Prince Edward County (ONT)	7 km	Sandy	Some algae after storms, litter	Rock rake attached to tractor	Daily	100,000
	Jones Beach	City of St Catherine (ONT)						
	Lake Ontario Park of Kingston	Kingston (ONT)	61 m	Rocky	Seaweed and dead fish	Manually removed with rakes	Daily	15,000
	Priar Park	Kingston (ONT)	31 m	Rocky	Seaweed and dead carp	Manually removed with rakes	Daily	Unpaid volunteers
	Couburg Beach	Couburg (ONT)		Sandy	Weeds, fish, rocks	York rake	Daily	
	Chatham Kent Municipal Beach	Kirkwood (ONT)	914 m	Sandy, with pebbles	Stones, sticks, weeds, dead fish, garbage	Harrows or rototiller	Daily	15,000-20,000
	Ontario Beach State Park	Rochester (NY)	805 m	Sandy, with pebbles	Seaweed, blue green algae, driftwood, garbage	Surf rake, Barber beach cleaner	Daily	
St. Clair								
	Lake St Clair Metropark	Lake St Clair (MI)	2.4 km	Sandy	Significant seaweed, dead fish, debris (wood), plastic	Beach groomer	Daily	28,000
	Belle Isle State Park	Detroit (MI)	398 m	Sandy	Very little deposits due to current	York rake	Daily	18,000
	Pier Park	Grosse Pointe Farms (MI)	137 m	Sandy	A lot of seaweed, dead fish, dead birds	York rake, tractor	Daily	3000
	Veterans Memorial Park	Lake St Clair (MI)	70 m	Sandy	Wood debris including branches, mostly seaweed, dead fish,	York rake, tractor	5x/week	15,000
Huron								

	Harrisville State Park	Harrisville (MI)	805 m	Sandy	Muck, pollen, shells, debris	York Rake, hand rake	10 hours/week	1275
	Negwegon State Park	Harrisville (MI)	4.8 km	Sandy	Muck, pollen, shells, debris	York Rake, hand rake	Weekly as needed	
	Cheboygan State Park	Cheboygan (MI)	91 m	Sandy		Hand Rake		
	Port Crescent State Park	Port Austin (MI)	4.8 km	Sandy	Debris, litter	York Rake	3 hours/week	405
	Harbor Beach City Park	Harbor Beach (MI)						
	Caseville County Park	Caseville (MI)	244 m	Sandy	Black muck, leaf debris	Tractor and loader bucket, hand rake	Before weekend, as needed	≥150 hours
	Sleeper State Park	Caseville (MI)	274 m	Sandy	Debris	Hand rake	As needed	Low
	Tawas Point State Park	East Tawas (MI)	152 m	Sandy	Litter, wood	Beach cleaner, hand pick up	Weekly, daily	Low/volunteer
	Sanilac County Park #4	Palm (MI)		Sandy	Litter, woody debris	York rake, hand rake	1-2 hours/week	191
	Forester County Park	Carsonville (MI)		Sandy	Litter, wood	Hand rake	12 hours/season	240
	Lakeport State Park	Lakeport (MI)	1.6 km	Rocky/sandy	Driftwood, woody debris	Tractor w/ attachment	Daily	128
Michigan								
	Peninsula State Park	Fish Creek (WI)		Underwater	Algae	Beach groomer	As needed	
	Wisconsin Office of the Great Lakes	Racine (WI)		Sandy	Algae, mussels	Beach curtain, beach groomer, hand raking	2-5 days/week	
	Kohler-Andrae State Park	Sheboygan (WI)		Sandy	Litter, fish, algae, invasive species	Hand raking	As needed	
	Holland State Park	Holland (MI)		Sandy	Debris, algae	York rake, Barber Beach Sweeper	Once a week	15,000 (purchase of sweeper)
	Ludington State Park	Ludington (MI)		Sandy	Debris, litter	Hand rake, tractor	Daily raking, tractor as needed	

	PJ Hoffmaster State Park	Manistee (MI)	4.8 km	Sandy	Litter, algae	Hand rake, Barber beach cleaner, Charrington beach cleaner, Large tractor	20 hours/week	2550
	Silver Lake State Park	Mears (MI)	6.4 km	Sandy	Algae, debris	York Rake	Monthly or as needed	
	Maranatha Resort	Muskegon (MI)	805 m	Sandy		Hand rake, machine grooming	5-10 hours/week	5000 for hand raking; machine grooming donated
	Saugatuck Dunes State Park	Saugatuck (MI)	4 km	Sandy	Litter, dead animals, industrial waste	Hand rake, tractor, sand fence		30,000 (purchase of tractor); 2250 (labor)
	JW Well State Park	Stephenson (MI)	91 m	Sandy	Debris	Hand rake, leaf blowing, beach comber tractor	Daily raking, leaf blowers every other day, beach combing 2x/month	375
	Moraine Hills State Park	McHenry (IL)			Litter, debris	Tractor	As needed	
	Indiana							
	National Lakeshore	Porter (IN)	24 km	Sandy	Litter, woody debris	Tractor, beach cleaner	Daily	12,600
	Onaway State Park	Onaway (MI)						
Erie								
	Presque Isle State Park	Erie (PA)	17.7 km	Sandy	Algae	Physical removal		
	Edgewater Beach	Cleveland (OH)		Sandy	70% wood, 20% trash, 5% leaf litter, 5% macrophytes	Cherrington beach cleaner, John Deere tractor	60 hours/week May through September. Sporadic off season.	54,000 (purchase of Charrington beach cleaner); 89,000 (purchase of John Deere tractor); 1520 hours (labor)

Dog Beach	Cleveland (OH)		Sandy	70% wood, 20% trash, 5% leaf litter, 5% macrophytes	Cherrington beach cleaner, John Deere tractor	60 hours/week May through September. Sporadic off season.	54,000 (purchase of Charrington beach cleaner); 89,000 (purchase of John Deere tractor); 1520 hours (labor)
Wendy Beach	Cleveland (OH)		Sandy	70% wood, 20% trash, 5% leaf litter, 5% macrophytes	Cherrington beach cleaner, John Deere tractor	60 hours/week May through September. Sporadic off season.	54,000 (purchase of Charrington beach cleaner); 89,000 (purchase of John Deere tractor); 1520 hours (labor)
Kelleys Island	Kelleys Island (OH)	30 m	Sandy		Tractor	Daily	
South Bass Island	Put-in-Bay (OH)	152 m	Rocky	Woody debris, mayflies, fish		Daily	Volunteer
Headlands State Park	Mentor (OH)		Sandy	Debris	Heavy machinery	4 days/week	
Lakeview Beach	Loraine (OH)	402 m	Sandy	Algae, driftwood, vegetation, garbage, tires	Barber swift rake	4-7 times/week	20,000
Conneaut Twp. Park	Ashtabula Co (OH)	804 m	Sandy	Vegetation, algae, garbage, significant driftwood	York rake pulled by tractor, hand rake	Daily	15,000
Huntington Beach	Cleveland (OH)	470 m	Sandy	Driftwood, litter, lake sediment	York rake, Cherrington beach cleaner, hand rake as needed	Daily	
Cleveland Metroparks	Cleveland (OH)	609 m	Sandy	Driftwood, lake sediments	York rake, Cherrington beach cleaner, hand rake as needed	Daily	

	Holiday Beach	(ON)	500 m	Sandy	Lots of vegetation, blue green algae blooms, logs, garbage, sewage overflow	York rake with tractor	Daily	10,000-15,000
	Lakeside Municipal Beach	St Catherine (ON)	250 m	Sandy	Algae blooms (20-60 metric tons removed, 3-4 days in a row in July/August)	York rake with tractor	5x/week	50,000
	Sunset Beach	St Catherine (ON)	300 m	Sandy, with pebbles	Algae blooms (20-60 metric tons removed, 3-4 days in a row in July/August)	York rake with tractor	Daily	50,000
	Jones Beach	St Catherine (ON)	300 m	Sandy, with pebbles	Driftwood, debris, algae buildup (20-60 metric tons removed, 3-4 days in a row in July/August)	Backloader, truck, York rake	Daily	50,000
	Laverne Kelly Memorial Park	Blenheim (ON)	914 m	Sandy with small pebbles	Stones, sticks, weeds, bird droppings, dead fish, garbage	Harrows or rototiller	Daily	15,000-20,000
Superior								
	Brimley State Park	Brimley (MI)	402 m	Sandy	Trees, driftwood, occasional black muck	Cut and remove, tractor rarely used	As needed	319
	Pictured Rocks National Lakeshore	Munising (MI)	64.4 km	Variable	Debris, fish			30,000
Inland								
	Young State Park	Boyne City (MI)		Sandy		Hand rake	As needed	
	Burt Lake State Park	Indian River (MI)	610 m	Sandy		Hand rake	As needed	

1 Many estimates were provided as hours/week with hourly rate. Annual costs calculated based on 15 weeks between Memorial Day and Labor Day. Estimates for labor, in dollars, unless otherwise noted.

Conclusion

The Great Lakes system collectively contain more than 20% of the world's fresh surface water, and is the world's largest freshwater ecosystem. This large lake system is bordered by eight states and two provinces across the United States and Canada. This large spatial range results in a variety of abiotic effects leading to equally variable beach maintenance practices. However, in reviewing beach management practices conducted throughout the Great Lakes there is a great deal of overlap. This is likely due to cost restrictions and a lack of new innovations to manage beach deposition in the Great Lakes.

Most beaches across the Great Lakes manage shoreline deposition on an as needed basis using manual removal, hand and landscape rakes. In extreme conditions, some beaches employ the usage of heavy machinery such as tractors, Cherrington and Barber beach cleaners, and tow away services. To offset costs, most beaches employing extreme measures have partnered with volunteer organizations, share heavy equipment with other state parks, or some combination of the two.

Management solutions: Possible options to control and manage Saginaw Bay nuisance muck.

Beach Management in the Saginaw Bay's Bay City State Recreation Area

Shoreline deposition of muck in the Bay City State Recreation Area (BCSRA) varies from year to year and consists of many types of organic debris. In addition to variation in muck composition, decomposition rates also vary annually (Stow et al. 2013). Muck composition and decomposition levels influence the consistency of muck which determines what management strategies can be employed. As a result, park managers at the BCSRA have employed various strategies to manage muck in the region.

In prior years, beach maintenance was performed on a volunteer basis by community groups. Since lake levels were dropping at this time, the BCSRA shoreline was inundated with muck. Due to increased deposition rates, community organizations were unable to keep up with shoreline deposition and muck accumulated at the BCSRA that compromised beach aesthetics.

In 2016, park managers at the BCSRA implemented new, more proactive management strategies resulting in less muck and fewer beach closures. These strategies focused on rapid response removals of macrophytes as they washed ashore. As of September 2016, plants had washed ashore 22 days over the course of the beach season. On average, the plants deposition was approximately one-foot-wide and one-half inch deep and totaled 47 cubic yards of removed organic material. In addition to rapid response removals of plant deposition, park staff grooms the beach with a landscape rake and tractor four times a week and volunteers from Friends of the BCSRA clean the beach with a beach cleaner once a week. If muck is present, it is removed twice a week. This costs the park a total of $900 in labor and $420 in fuel per season. Park managers have prioritized and coordinated beach management with park staff and volunteer organizations. As a result, beach aesthetic has improved and attendance has increased. These efforts may have been enhanced by elevated water levels in 2015-2016, which may have led to a reduction in shoreline deposition at the BCSRA.

Despite ongoing and intensified efforts to address the muck issue, however, both agencies and stakeholders involved are not satisfied with current management strategies as a cost-efficient, long-term solution to the issue. As such, this IA included two workshops aimed at developing a series of feasible management actions that can be implemented at the BCSRA (and greater Saginaw Bay) to address both short- and long-term strategies for managing and/or controlling muck. Each workshop included a select group of technical experts to assist in achieving this goal through a sharing of group expertise and experience, as well as the involvement of multiple community experts and other stakeholders. This interdisciplinary approach is critical for the success of this initiative and should foster interactions between researchers, managers, and public interest groups. The first workshop was held on September 22, 2014 (agenda and invited participant list in Appendix 5A). The aim of this workshop was to finalize a list of potential management strategies and to better understand past management efforts in Saginaw Bay. The data for the latter aim is found in Appendix 5B. The second workshop was held on November 20, 2014 (agenda and invited participant list in Appendix 5C). The aim of this second workshop was to determine the feasibility of management strategies proposed in the first workshop. The outcomes of these workshops are presented below, and summarized in Table 5.2.

Table 5.2. Summary of muck management strategies, based on workshop outcomes.

Options	Anticipated impact		Cost				Permit required		Modeling Potential (Y/N)
	Short term	Long term	Low <10,000	Medium 10-100k	High >100k	Continuous	State	Fed.	
1.1 Physical Removal of muck: Beach grooming beach raking									
Management response	X			X		X	X	X	N
Stakeholder response	X			X		X		X	N
1.2 Beach Dredging: Physical removal of littoral muck									
Management response	X		X	X	X	X	X	X	N
Stakeholder response	X								
1.3 Physical removal of open water benthic algae									
Conventional muck removal strategies (open water)- muck sucker									
Management response	X				X	X	X	X	N
Stakeholder response	X	X		X		X	X	X	N
Gas powered sludge pumps									
Management response	X				X	X	X	X	N
Stakeholder response	X	X		X		X	X	X	N
Hydraulic pumps and conveyor systems									
Management response	X				X	X	X	X	N
Stakeholder response	X	X			X	X	X	X	N
1.4 Muck rerouting via barriers around the BCSRA									
Permanent barriers (Jetties)									
Management response		X			X	X	X	X	Y
Stakeholder response		X			X	X	X	X	Y
Permanent barriers (Commercial Piers)									
Management response		X			X	X	X	X	Y
Stakeholder response		X			X	X	X	X	Y
Removable Barriers (Containment Booms)									

Options	Anticipated impact		Cost				Permit required		Modeling Potential (Y/N)
	Short term	Long term	Low <10,000	Medium 10-100k	High >100k	Continuous	State	Fed.	
Management response	X				X	X	X	X	Y
Stakeholder response	X				X	X	X	X	Y
Removable Barriers (Floating Docks)									
Management response	X				X	X	X	X	Y
Stakeholder response	X				X	X	X	X	Y
1.5 Impoundment to alter flow (control floating muck)									
Management response		X			X	X	X	X	Y
Stakeholder response		X			X	X	X	X	Y
1.6 Altering agricultural practices in the Saginaw Bay Watershed									
Increasing limitations on agricultural nutrient loading and phosphorus									
Management response	X	X			X	X		X	Y
Stakeholder response		X			X	X			Y
Enhanced phosphorus removal protocols									
Management response		X				X	X	X	Y
Stakeholder response	X	X			X	X			Y
Best management practices (BMPs) and generally acceptable agricultural management practices (GAAMPs)									
Management response		X				X			Y
Stakeholder response		X							Y

1.1 Physical removal of muck: beach grooming via shoreline beach raking

Introduction to beach grooming

The physical removal of muck refers to the removal of muck from sandy beaches in a variety of ways. The methods of removal can range from organizing groups of volunteers and park employees to walk the beach and rake by hand, to the use of tractors with large rakes that are pulled behind to remove debris and organic matter. Due to its potential benefits (i.e. removal of muck debris at a moderate cost), beach grooming is a widely-utilized form of maintenance, however, recent studies have indicated that grooming practices may compromise ecological systems.

The overall benefits of beach grooming are obvious as the continued presence of shoreline refuse can be detrimental to beach recreation and threaten the tourist economy. However, applying beach grooming practices to muck management can be complex with several disadvantages. Shoreline muck in the BCSRA consists of a variety of organic debris that varies from year to year (Stow et al. 2013). As such, beach grooming practices may have to be adjusted annually which could incur inconsistent costs and complicate planning. Additionally, nuisance muck at the BCSRA is known to be a deposition zone for pathogenic *E. coli* bacteria which is commonly imbedded in beach sand left behind after the physical removal of muck (Kinzelman et. al 2002).

Beach grooming practices also physically alter beach sediment texture as significant quantities of fine sand is commonly shifted or removed with unwanted debris. This subtle change should be considered as significant changes in biodiversity often coincide with the implementation of beach grooming (Dugan and Hubbard 2009). Strict regulations have been imposed on maintenance of sparse shoreline vegetation which grows between the ordinary high water mark (OHWM) and the water's edge. This shoreline vegetation provides habitat and refuge from desiccation for macroinvertebrate species (Jones et al. 2008). Reduction in macroinvertebrate biodiversity may have cascading effects through trophic levels as nesting shore birds and other native fauna rely on their presence for nutrition. Additionally, the removal of fine sands may limit nesting habitat for birds, turtles, and fish (Dugan et al 2011).

With the removal of fine surface sand from recreational beaches, beach grooming practices also impact wind erosion. Rough, coarse sands have greater surface area than finer sands which may enhance the effects of erosive wind in near and far shore areas where beach grooming has taken place. This may have long term effects, inciting eventual change to the overall structure of the shoreline over time (Kelly 2014).

On recreational beaches that are historically used for tourism and recreation such as the BCSRA, the overall effect of beach grooming may be negligible as routine anthropogenic activities reveal similar stressors to shoreline ecosystems. Although beach grooming could be considered undesirable from a conservation standpoint, mitigation strategies to reduce impact could entail alternating areas of uncleaned beach with groomed sections. This would allow for functional grooming to provide clean beaches for recreation at the BCSRA. However, this strategy is palliative, and therefore a near-term solution, in that it addresses only the symptoms without controlling the many sources of nuisance muck problems in Saginaw Bay.

Stakeholder and public involvement in beach grooming success

There are several instances where beach vegetation and muck have been managed successfully by researchers, volunteers, and the park service. Previously, resource and park managers have attempted to inspire and involve the public in beach grooming activities. This is essential, as robust public and stakeholder involvement is crucial to the success of beach management programs in terms of staffing activities and reduction of cost.

Utilizing volunteer groups for environmental remediation under the guidance of program managers and stakeholders has been a successful maintenance method in the past. In 2011, a group of Bay City residents acting independently organized an Earth Day beach clean-up at the BCSRA as a part of the Great Lakes' Adopt-a-Beach program. This program went a step beyond simply picking up trash and grooming the beach, involving the public in gathering data on water chemistry, wind, and algal sampling.

Staffing for beach grooming activities

Beach grooming events at the BCSRA will be planned by the Michigan DNR and United States National Park Service. Beach grooming activities will be staffed with park employees and volunteers will be utilized when available. Park employees and volunteers participate in beach grooming activities under recommendations from the project management team and stakeholder groups.

Permits needed for beach grooming in Michigan's Great Lakes

State permitting:

Historically, maintenance of the Michigan shoreline surrounding the Great Lakes has been regulated by state permits issued through the Michigan Department of Environmental Quality (MDEQ). These regulations were amended under law passed in 2012 entitled 2012 PA 247, Senate Bill 1052 whereby a permit would not be required to maintain shoreline property in areas between the ordinary high water mark (OHWM) and the water's edge. These activities were formerly regulated under National Resources Environmental Protection Act (NREPA), 1994 PA 451. The specific activities that are no longer regulated under NREPA, 1994 PA 451 are described below:

"In areas below the OHWM and above the water's edge where sediment is predominantly sand, cobble and rock and vegetation doesn't ordinarily grow, is sparse and not acclimated to wetland conditions. Any combination of the following beach grooming practices may be implemented without state level permitting requirements.

- Sand leveling as described by the redistribution of sand via spreading and grading.
- Removal of vegetation by hand or shallow tilling.
- Grooming of sand, cobble, and rock through removal of debris through raking. Law requires it not to disturb or destroy plant roots.
- Trash, dead vegetation, and animals.

Mowing is acceptable so long as soil and plant roots remain undisturbed."

Federal permitting:

Although permitting requirements for shoreline maintenance are no longer required on the state level, federal permits are still required and can be obtained through from the U.S. Army Corps of Engineers (ACOE; Kart 2015). The ACOE retains jurisdiction over exposed bottomlands, sand leveling, and the grooming of sand or vegetated areas between the ordinary high-water mark and the water's edge in the Great Lakes.

Short term costs for beach grooming

With over 2800 acres at the BCSRA, beach cleaning should be performed at some scope daily. Cost is dependent on the amount of beach groomed and the amount of muck removed. High water levels may reduce cost as less beach is exposed, with lower muck deposition. The costs of this short-term management strategy should be assessed on a per week/month/seasonal basis and may include the following:

- Employee cost.
- Federal permits for shoreline maintenance permits from the ACOE.
- Equipment rental or purchase: Surf Rake, Sand Man, etc.
- Supply costs.

Long term costs for beach grooming

Cost also needs to be interpreted on a long-term scale as the beach grooming is an ongoing process. As such, it is necessary to predict and assess costs based on long term time investment.

- Long term employee costs.
- Equipment rentals/sharing.
- Long term supply costs.

1.2 Beach Dredging: The physical removal of littoral muck

Introduction to beach dredging

While beach grooming consists of scraping, grading and removal of debris between the OHWM and the water's edge, beach dredging is directed toward the physical removal of muck from the littoral zone with heavy machinery. The littoral zone of lakes is typically defined as the near shore, submerged region where sunlight penetrates to the sediment allowing for the growth of photosynthetic aquatic plants referred to as macrophytes. Though operating machinery in the littoral zone of lakes is highly regulated and time consuming, beach dredging practices have been a successful form of maintenance in the

Great Lakes and BCSRA. This strategy is also palliative, and therefore a near-term solution, in that it addresses only the symptoms without controlling the many sources of nuisance muck problems in Saginaw Bay.

A principal factor in the proliferation of muck at the BCSRA is increased productivity of macrophytes in the littoral zone of Saginaw Bay. There are numerous contributing factors such as the proliferation of zebra mussels and nonpoint nutrient deposition from agricultural land surrounding the Saginaw River (Stow et. al 2013). As macrophytes die off in the littoral zone, they are released from the sediment and enter the water column and collect with benthic algae where they are deposited into the littoral zone and washed ashore (Francoeur et al. 2014). The benefit of littoral dredging is that muck is removed from the system before it contacts the shoreline, and beach fouling occurs.

Dredging processes are very versatile and widely used in the management of aquatic systems. The uses of dredging range from widening of canals and procurement of bays, to the removal of littoral sand to replenish shoreline beaches. This method of shoreline maintenance has been used with some success in the BCSRA, however, these are costly processes that may need to be repeated over the course of the season. In addition, due to the size of the equipment, dredging may be limited based on sufficient beach access infrastructure.

One benefit of using beach dredging for muck removal is that the rewards are instantaneous as muck can be transported away from the shoreline. However, rental and licensing of bulldozers, excavation equipment and qualified operators can be costly. Additionally, there are environmental concerns over the translocation of what could be considered small scale ecosystems residing in littoral sand (Work et al. 2004). As such, the ecological consequences of beach dredging are hotly contested and the discharge of dredged sediments into United States waters is highly regulated.

Dredged material management in the Great Lakes

Disposal of the dredged material is also an issue in beach dredging. It has been reported that nearly 5 million cubic yards of sediment is dredged from the Great Lakes basin annually. Dredging projects may be small, such as a single pipeline crossing, which may entail relocation of 10-100 cubic yards of sediment. Conversely, some projects are very large, such as the construction of large commercial harbors, which have been reported to require the movement of up to 500,000 cubic yards of sediment (Thorp 1996).

Methods used to dredge lake sediments vary based on the size of the project. Methods commonly used for dredging include mechanical buckets, drag lines, and hydraulic dredges that transport sediment through pipelines or in large hoppers (Barnard and Hand 1978).

The following are the classifications in which dredged material management may be categorized ("Contaminated Sediments Program." n.d. EPA).

- Open water placement (32% of Great Lakes dredged material) concentrates on the relocation of hydraulically and mechanically dredged materials. Hydraulically dredged materials, which are usually smaller quantities of dredged materials, are commonly moved through pipelines and deposited just offshore. Mechanically dredged sediments, however, are often relocated using barges and scows to dumpsites that are greater distances from the shoreline. Dredged materials are either deposited into the water column where they will settle into bottom sediments, or remain in a mound at the dumpsite depending on the physical properties of the sediment and hydrodynamics of the deposition zone.
- Beach and littoral nourishment (12% of Great Lakes dredged material). Beach nourishment involves the movement of dredged materials to the shoreline where fine sand contributes to the existing beach. Littoral nourishment moves dredged materials into the near shore littoral zone.
- Beneficial use includes the above listed practices of beach and littoral nourishment, but also includes upland usage. Upland usage of dredged sediments may include wetland replacement, construction, landscaping, and agricultural applications. To practically use dredged materials for upland uses, temporary storage facilities such as a confined disposal facility (CDF) must be used for drainage and washing ("Facts about Confined Disposal Sites" n.d. 2010). Beneficial uses of dredged materials have also included the construction of islands for wildlife habitat. Programs are currently in place where the ACOE can assist in federal funding provisions to encourage the use of dredged materials for protection, conservation and enhancement of wetlands and aquatic wildlife habitat.
- Capping refers to the physical containment of dredged material in a sub aqueous site. Two types of capping are commonly used in the disposal of dredged materials; confined aquatic disposal (CAD) and level bottom capping. Confined aquatic disposal uses an existing or physically excavated depression to provide

lateral containment and cap the dredged sediment with a clean material. Level bottom capping simply deposits the contaminated dredged material on the lake bottom where it is covered by a clean material. The "clean" material used for capping is generally sandy dredged material. This process has not been used in the Great Lakes region.

- Confined disposal is used when capping and beneficial use of dredged material is not environmentally feasible. In this case, CDFs are diked structures used to contain contaminated dredged materials. The physical features of confined disposal areas vary with the nature of the dredged sediment in question. In cases of environmental clean-up dredging, commercial landfills may be used.

Permits needed for maintenance dredging in Michigan's Great Lakes

State permitting:

In the state of Michigan, permits are required for dredging lake and river bottoms. Permit applications are pursuant to Part 325, Great Lakes Submerged Lands or Part 301, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended in 2012 ("MDEQ Dredge Sediment Review" n.d. 2013). The Water Resources Division (WRD) issues permits for dredging projects, and dredge material characterization is required by the Department of Environmental Quality (DEQ). Sediment testing is required, and results must be submitted with applications and evaluated along with the proposed project ("MDEQ Dredge Sediment Review" n.d. 2013).

The Michigan DEQ requires that the Water Resources Division (WRD) determine whether sediment testing is required prior to issuing a permit. This determination is made based on the quantity of material designated for dredging and likely site contamination. If more than 2000 cubic yards is designated to be dredged or if there is on site contamination or if WRD field staff believes that contamination is likely, the site is marked as a designated test area ("MDEQ Dredge Sediment Review" n.d. 2013).

If testing is not required or is waived, the proposed project is entered into the Coastal and Inland Waters Permit Information System (CIWPIS), and the project can move forward. If testing is necessary, the applicant will receive a Sediment

Testing for Dredging Projects letter from the WRD field staff. Under the guidance of the WRD field staff, the testing requirements stated in the Sediment Testing for Dredging Projects letter must be met and a copy of the letter and application are provided to the Office of Waste Management and radiological Protection (OWMRP) district supervisor for approval ("MDEQ Dredge Sediment Review" n.d. 2013).

Federal permitting:

The Army Corps of Engineers (ACOE) estimates that an expenditure of nearly $20 million for maintenance dredging projects and 100 dredging permits are issued annually ("Contaminated Sediments Program" n.d. 2016). Permits are issued under section 404 of the Clean Water Act (CWA), however, the state also plays a role in issuing 404 permits under state program general permits, water quality certification and program assumption ("Section 404 Permitting" n.d. 2015).

Section 404 of the CWA was established to regulate discharged dredge material into the waters and wetlands of the United States, however, there are exemptions from 404 regulations. Typically, a permit under section 404 is not necessary if discharges of dredged materials are sourced in farming, ranching and forestry such as plowing, cultivating, minor drainage and production of food, fiber, and forest products. Additionally, conservation practices directed towards upland soil and water along with long term farming and forestry operations are not regulated under section 404 ("Section 404 Permitting" n.d. 2015).

For activities that may require a section 404 permit under the CWA, a proposal must go under review from the ACOE. These permits are reserved for dredging activities which may bear significant environmental impacts. However, less impactful dredging activities may be passed on a general permit. General permits are issued on federal, regional and state levels and allow activities to proceed without delay if all permit requirements are met ("Section 404 Permitting" n.d. 2015).

Short term costs for beach dredging

The short-term costs relating to beach dredging may appear significant as there are many rentals, purchases, and licensures necessary to effectively move forward with this process. However, this procedure has been an effective strategy for muck management at the BCSRA despite the following costs:

- Machines: dozers and excavation equipment rental or machine purchase.
- Hiring of licensed machinery operator on a part time/full time basis.
- Hiring of employees or recruitment of volunteers.
- Federal and state permit costs.
- Supply costs.

Long term costs for beach dredging

To perform effective beach dredging, it must be coordinated with other types of beach maintenance to be effective. Beach dredging must also be performed many times over the course of the beach season. In doing so, there may be economic consequences as sections of beach must be temporarily closed while beach dredging practices are active. Long-term costs include:

- Machine rental or purchase for use over multiple seasons.
- Long term machinery operator costs.
- Long term staffing of employees and recruitment of volunteers.
- Economic losses due to beach closures.
- Supply costs.

1.3 Physical removal of open water benthic algae using a "MuckSucker" – or similar vacuum type device.

Introduction to the physical removal of open water benthic algae

Complications in the characterization of benthic algal mats may obscure predictions of decomposition rates of benthic algal species, which may be reflected in deposition rates of algal mats to the BCSRA shoreline. With that knowledge, numerous open water muck removal strategies have begun to be developed to intercept benthic algal mats before they enter the littoral zone and are deposited upon the BCSRA shoreline.

Methods have been developed for the removal of open water benthic algae through a suite of muck removal tools. With the development of these tools, the emergence of several entrepreneurial groups such as Sediment Removal Specialists (SRS), Unicorn Muck Suckers, Joy Global and others have capitalized on a new environmentally conscious industry in an effort to assist in the control of muck in lakes, reservoirs, and ponds. Not only do these companies engage in the initial restoration of muck fouled waters, but they also offer follow up maintenance work to continue in the reduction of persistent nuisance muck problems.

Conventional benthic muck removal strategies

Historically, dredging methods have been used to control open water muck problems. This process has involved the use of heavy machinery such as bulldozers and excavation equipment for the physical removal of muck. These are adequate methods for muck removal from the littoral zone of water bodies, however, these practices when applied to the open water zones of water bodies have dire environmental consequences.

When using conventional dredging to control open water benthic algal mats, water is drained from the system and heavy equipment is used to scrape away unwanted muck from the lake bed ("mucksuckers" n.d. 2015). After this process, unwanted muck must be hauled away where it is then burned off or stored at an appropriate dump site. During this process, much of the local flora and fauna must be temporarily relocated, and costly reclamation processes must follow to restore the landscape to its original form. This inconvenient process has little application in sites as large as Saginaw Bay and the BCSRA.

Emerging benthic muck removal strategies

Current practices of open water muck removal may be more applicable to larger sites as they are more attentive to the preservation of local flora and fauna and do not require complete removal of desirable wildlife. Modern methods preserve wildlife by reducing disturbance of the system. Although many of these methods utilize the application of heavy machinery, in most cases the heavy machinery is either sedentary within the system or are contained and operate from large boats and barges to minimize negative ecological consequences. Severe ecological consequences could be incurred, however, if equipment is pulled through a sensitive or nursery area.

Gas powered sludge pumps

In localized cases where open water benthic algae has run amuck, use of gas powered vacuum devices called sludge pumps are adequate for remediation of lakes, ponds, and reservoirs. Companies such as SRS and Unicorn Muck suckers specialize in the removal of open water benthic muck by employing HAZWOPER (hazardous waste operations and emergency response standard) certified divers as sludge pump operators. In these cases, benthic muck is removed manually which may require excessive manpower and incur significant costs for staffing and sediment transport, and is associated with dangerous conditions for divers.

The process of manual muck removal with sludge pumps entails sludge pump operators who dive to the lake bed and use high powered suction devices to remove muck and fouled sediment. The organic material and sediment are suctioned out and placed in containment units and hauled away to an adequate dump site for disinfection and remediation.

Transport of wet sediments can be expensive as hauling costs are commonly determined by weight. To reduce hauling costs, it is advised to repurpose benthic algal sediments as fertilizer and landscaping material, or allowing it to dry on drying beds prior to removal (Walkington 2009).

Hydraulic pumps and conveyor systems

Large scale open water muck removal operations require a greater rate of removal than can be offered using manually operated, gas powered sludge pumps. In these cases, it is recommended that larger, hydraulic and machine driven pump systems be used. Heavy machinery that is typically used for the removal of open water muck feature either large tilling wheels or hydraulic dredges or pumps that comb the bottom of the lake bed where they physically remove, and deposit high volumes muck and fouled sediments onto a series of conveyor belts. These conveyors then transfer open water muck and sediment into containment devices for transport. High volume, open water muck removal systems can be sedentary, where they are planted in specific muck deposition zones throughout the water body, or mobile barges that can accommodate heavy machinery and muck removal containment units (Walkington 2009).

Large scale open water muck removal operations can be arduous, and the selection of how and when to utilize these machines is critical to the success of the operation. For instance, in the use of barge mounted hydraulic pump and conveyor systems, it is important that the waters be relatively calm and that beach populations be low to protect beach goers if open water muck is released and escapes into swim zones. It may be best to perform these operations when winds are mild and wave action is minimal, such as morning hours (Walkington 2009). Since large scale muck removal operations yield higher quantities of free nuisance muck, innovative post removal management and transport options must be derived. It has been suggested that tunnel muck removal techniques be used to concentrate the large quantities of benthic muck, and separate it from water and sediment prior to transport. Possible techniques for muck concentration are to use rotary drum thickeners that use minimal quantities of polymers to chemically treat and separate muck from water and sediment ("think tech" n.d. 2015), centrifuges, sand drying beds and belt presses (Walkington 2009). Since large quantities of lake water and sediment will be removed with benthic muck, this separation will allow the safe return of clean water and sediment to the system post treatment.

Successes in open water muck removal

Though the process of open water muck removal is relatively new, some freshwater lakes such as Lake Osbourne in southeast Florida have tested it. Lake Osbourne was suffering from the typical characteristics of a eutrophic system; low concentrations of dissolved oxygen, algal blooms, stifled aquatic wildlife and a layer of benthic muck that hadn't been managed for years. In 2004, resource managers hired a Wisconsin company, J.F. Brennan Co., to remove 100,000 cubic yards of benthic muck using a 48-foot hydraulic dredge (Santaniello 2004).

As the effectiveness of this process was previously unproven, resource managers elected to begin with the removal of 20,000 cubic yards of benthic muck. Since this process was successful, J.F. Brennan Co. continued to remove an additional 80,000 cubic yards. Although this quantity only represented clearing just under 15% of Lake Osbourne's benthic muck, it was enough to fill over 5,500 dump trucks (Santaniello 2004).

Benthic muck management in Lake Osbourne has been expensive with estimated costs of nearly $1.14 million for muck removal alone, $1.17 per square foot of bottom cleanup. After screening muck through a series of filters and chemical treatments, nutrient rich, clean muck has been repurposed to fertilize park and county golf course vegetation (Santaniello 2004).

Permitting for open water benthic muck removal

Much of the federal and state permitting necessary to perform open water benthic algal muck removal with heavy machinery is similar to the permitting required to perform littoral beach dredging. This requires obtaining a Part 325, Great Lakes Submerged Lands or Part 301, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended in 2012 on the state level ("MDEQ Dredge Sediment Review" n.d. 2013), and a permit issued under section 404 of the Clean Water Act (CWA) ("Section 404 Permitting" n.d. 2015) on the federal level. However, additional permitting is required to return clean discharge and sediment back into open waters. These permits are issued through the MDEQ and are called National Pollutant Discharge Elimination System (NPDES) discharge permits ("NPDES Permit Program Basics." n.d. 2015).

National Pollutant Discharge Elimination System (NPDES) discharge permits were introduced in 1972 along with the Great Lakes Water Quality Agreement (GLWQA) to regulate point source pollution in United States waterways. Most frequently, point sources are conveyances such as man-made ditches and drainage pipes, but in this case the point source would be the safe return of treated water and sediment that has been separated from benthic muck back to the open water of Saginaw Bay.

There are two discrete types of NPDES permits issues through the MDEQ: an individualized permit and a general permit. Individualized permitting is tailored to a specific facility's needs by the permitting authority, and covers a specific potential point source discharge practice for a specific period not to exceed five years. General permitting covers several facilities engaging in a single, specific point source practice. General permits may be more appealing since cost is reduced due to several facilities being covered under practices sharing a common element. This is allowed under NPDES statute 40 CFR 122.28 ("NPDES Permit Program Basics." n.d. 2015).

These permits are issued through a proposal based format where interested parties submit applications for review and develop technologies to limit discharge of contaminated effluent and sustained monitoring practices in accordance with 40 CFR 124. ("NPDES Permit Program Basics." n.d. 2015).

Short term costs for open water benthic muck removal

The greatest expenditures for open water benthic muck removal are initial costs. The equipment used for muck removal are seasonally sedentary or large watercraft containing heavy machinery consisting of hydraulic pumps and conveyors, as well as devices designed to separate muck from water and sediment such as rotary drum thickeners, centrifuges, and belt presses. This is because the highest volumes of muck are to be removed from the system requiring the largest quantity of equipment and manpower. Costs include:

- Hiring of consultants/companies to plan short term muck removal.
- Large muck removal equipment purchase or rental which includes barges, hydraulic pumps, and conveyors.
- Water, sediment, and muck management equipment such as rotary drum thickeners, centrifuges, and belt presses.
- Hiring of machinery operators and staff.
- Federal and state permitting costs.
- Supply costs.

Long term costs for open water benthic muck removal

Long term costs for open water benthic muck removal are proposed to be lower than those seen in the short term. The highest volumes of muck removal will take place during the short-term phase of the project using the largest, most expensive machines and requiring the highest fees for consultants and staff. In the short term, smaller staff and machinery such as gas powered sludge pumps may be used as methods of maintenance in the BCSRA. Long term costs include:

- Large muck removal equipment purchase or rental which includes small boats, rafts and gas powered sludge pumps.
- Water, sediment, and muck management equipment such as sand drying beds.
- Hiring of operators and required staff.
- Supply costs.

1.4 Muck rerouting via barriers around the BCSRA

Introduction to the use of muck rerouting

Though benthic algae and macrophytes are significant contributors to the nuisance muck problem at the BCSRA, algae suspended in the pelagic zone must also be addressed. The pelagic zone of lake systems includes all areas of the lake aside from the lake floor and coastline. The pelagic zone is divided into two distinct regions, the photic and aphotic zones. The photic zone is an area where light can penetrate and primary production may occur. If algae is not removed from the water column by primary producers, it may fall through the aphotic zone, into the benthic zone and die off. If pelagic algae can be redirected prior to its accumulation in the benthic zone, nuisance muck in the BCSRA may be more easily managed.

Muck rerouting through the installation of barriers around the BCSRA may be a viable management technique in the control of pelagic algae and shoreline muck deposition. These installations would act as wave breaks, interrupting nuisance muck before it contacts the BCSRA shoreline. With appropriate engineering and planning, permanent or removable barriers could reroute muck to a chosen destination allowing for grooming and dredging. However, there are concerns with the construction, annual maintenance, and ecological consequences of such structures.

Permanent barriers could present in the form of jetties, jetty spurs, and commercial piers. Permitting for the construction of jetties and jetty spurs, which would involve relocation and restructuring of Great Lakes bottomlands, would prove difficult as this may compromise the habitat of fish and other aquatic wildlife. The use of commercial piers as permanent barriers may also present permitting concerns, and the construction of such structures may be costly. However, renting pier space to vendors may assist in offsetting such costs. Due to complicated permitting, and costly maintenance of permanent barriers in the BCSRA, resource managers may view removable barriers as a more practical solution.

Removable barriers such as containment booms and floating docks may be a more controlled method in rerouting muck in the BCSRA. Though floating docks do not make direct contact with the lake bottom, they are sufficient for breaking up wave action to control muck deposition upon the shoreline. Containment boom systems have a more direct effect as they contact muck throughout the water column and are mobile enough to be adjusted in response to wind changes and seiche events. Permitting for removable barriers may be simpler than that of permanent barriers due to their indirect effect on Saginaw Bay bottomlands.

Use of physical barriers to control muck

Permanent barriers

Jetties: A jetty is defined as a small structure that moves out from the land into water. These surface piercing structures are typically placed in rivers and bays to control discharge areas and promote scour. If appropriately engineered, jetties should extend outwards from shore into open water and redirect mixed sediment from the water column. Jetties are frequently used to deter these sediments from entering lagoons as well as control currents in ship channels (Hickson et al. 1950).

The types of jetties selected for use are dependent on their purpose and physical characteristics of the site. Due to high winds and seiche events in Lake Huron and Saginaw Bay, jetties constructed to control sediment and muck deposition would have to be substantial structures. In the BCSRA, this could include solid fill structures composed of rubble and reinforced concrete laid on solid foundations. Caisson jetties may be selected for this purpose as they are composed of rubble stone foundations and feature heavy stone riprap to prevent weathering and resistance against erosion (Hickson et al. 1950).

Jetties can be augmented so that there are small jutting, submerged structures called jetty spurs to further control wave action and muck deposition. The angle with which the jetty spur is facing determines its effect upon the current. Numerical modeling has revealed that when the approaching waves break upon the seaward end of the jetty spur, and progresses in an upward manner along the jetties face, the deflection of currents along the jetty axis will be enhanced (Seabergh et al. 2008). Jetty spurs may also control currents and wave breaks prior to contacting the jetty, and contribute to the overall stability of the structure.

Commercial peers: A pier can be defined as a support platform raised above the water by permanent pillars or piles that penetrate the water's surface and are mounted in lake sediments. These structures extend from the shoreline over water and are typically designed to support walkways, bridges, and arches. Piers serve important functions to the bayside economy as they provide access to water for recreational activities such as swimming, boating and fishing.

The use of commercial piers as wave breaks can serve a dual purpose at the BCSRA as they slow muck deposition, while supporting recreation and providing vendor space. The permanent pillars and piles of piers are useful in the attenuation of waves and currents. If strategically placed, these structures can assist in the rerouting of muck to a desired location to be dredged and removed, and the beach to be groomed.

Removable barriers

Containment booms: Containment booms can be defined as temporary barriers constructed of filter screens designed to contain environmental contaminants for removal using skimmers and vacuums. These devices are utilized to remediate aquatic oil, chemical spills, and contaminated sediment. Containment booms come in a multitude of shapes and sizes and can feature project specific designs.

There are three main kinds of aquatic containment booms: hard boom, sorbent booms and fire booms. The hard boom is the most versatile form of aquatic containment boom, while sorbent and fire booms are tailored to the recovery of oil spills. The hard boom, which could be used for muck rerouting in the BCSRA, features a tubular floatation mechanism connected to a weighted mesh skirt that drops to the bottom of the water column (“Spill containment methods” n.d. 2015). Hard booms can be mounted in place, or have each end connected to a boat or barge allowing mobility in the directed collection of contaminated sediment.

There are companies, such as Gunderboom, which may tailor containment boom systems for specific remediation projects. Gunderboom fabricates aquatic barrier systems taking into consideration site characteristics, parameters, and project goals. The geo-composite materials used in Gunderboom mesh can be porous and have very high tensile strength which can retain contaminated sediments while allowing water to pass ("Gunderboom Technology and Projects Overview." n.d. 2015). Gunderboom has had successful site recovery projects in riparian, freshwater and coastal marine systems.

Floating docks: Floating docks support a similar function to that of commercial piers. Like commercial piers, floating docks may provide wave breaks that slow down the movement of pelagic algae through the water column. This slowing of pelagic algae may reduce pelagic contribution to existing benthic algal mats. Because of controlled wave action, benthic mats may be retained in the lake bottom, significantly reducing nuisance muck deposition at the BCSRA shoreline.

Unlike commercial piers, floating docks are not mounted to pillars in lake sediments, but are attached to pilings in lake sediments. This attachment strategy permits floating docks to freely move with water levels. As such, floating docks are typically less substantial structures than commercial piers and can be more adaptive to high winds and seiche events in Saginaw Bay.

Successes using barriers for muck rerouting

The use of permanent barriers such as jetties and piers is common in the control of sediment deposition in aquatic systems. Though significant engineering and planning are required in the successful implementation of jetties, it is the primary method to control sediment deposition in lagoons and shipyards. Commercial piers have numerous positive effects in control of waves and currents in freshwater and coastal marine systems. Their positive effects are not only practical, but intrinsic as they can have positive aesthetic effects as well.

Removable barriers have also been successfully used in the recovery and management of aquatic systems. For instance, Gunderbooms have been utilized for purposes ranging from marine life exclusion near cooling water intake systems near the Hudson River in New York, to sound and sediment attenuation during the construction of the Oakland Bay Bridge ("Gunderboom Technology and Projects Overview." n.d. 2015).

Permitting for using barriers for muck rerouting

To construct piers and jetties in navigable waters of the Great Lakes, permitting at the state and federal level is required. In the case of permanent and semi-permanent structures such as these, Great Lakes bottomlands must be disrupted. Great Lakes bottomlands are protected through numerous statutes via National Resources Environmental Protection Act (NREPA), and through the Code of Federal Regulations (CFR).

State permitting for the construction of piers and jetties appears under the marina construction permit program through the NREPA as presented by the Michigan Department of Environmental Quality (MDEQ). Michigan legislation states that piers and jetties which are subjected to ongoing, non-seasonal use must be permitted under part 301, inland lakes and streams, and Part 325, Great Lakes Submerged Lands, of the NREPA, 1994 PA 451 (“MDEQ Dredge Sediment Review” n.d. 2013). The language used in section 30101(u) delineates included structures as a marina wharf, dock, pier, dam weir, stream deflector, breakwater, groin, jetty, sewer, pipeline, cable, and bridges ("Marina Construction Permits." n.d. 2015).

The Army Corps of Engineers (ACOE) and the Department of Army (DA) issues permits to authorize construction of certain structures which may influence the navigable waters of the United States. These permits are pursuant of section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 403). Permitting for construction of jetties and piers requires adherence to the general policies of 33 CFR Part 320 and procedures 33 CFR

Part 325 ("Permits for Structures or Work in or Affecting Navigable Waters of the United States." n.d. 2015), and issuance of permits for discharges of dredged or fill material into waters of the United States as described in section 1.2.3.2. ("Permits for Structures or Work in or Affecting Navigable Waters of the United States." n.d. 2015).

Short term costs for muck rerouting

The short-term costs necessary to install commercial piers and jetties to control muck deposition at the BCSRA will be significant. The short-term construction costs to build structures substantial enough to withstand abiotic pressures in Saginaw Bay require extensive permitting, materials, and labor. The greatest impact of cost is likely to be seen on the front end of permanent barrier construction in Saginaw Bay:

- Construction costs of jetties and piers.
- Consultation and custom construction of containment booms and floating docks.
- Federal and State permitting costs.
- Supply costs.

Long term costs for muck rerouting

With the greatest financial installments for the implementation of permanent and removable barriers in Saginaw Bay occurring early in the construction of these structures, most of the long-term costs would pertain to maintenance and staffing. Though these costs may still be significant, most of the costs will be shown early in the project:

- Staffing of seasonal maintenance of piers, jetties, and floating docks.
- Routine operation of containment boom systems.
- Supply costs.

1.5 Use of impoundments to influence flow and control floating muck

Introduction to using impoundments to influence flow

Impoundments such as manmade bays and coves could be used in Saginaw Bay to influence flow and trap muck prior to contact with the BCSRA shoreline. These impoundments would be used to intercept and contain floating muck, where it could be separated from water and removed. Water could then be treated and discharged back into Saginaw Bay.

Coves can be described as small, protected bays with narrow, restricted entrances. Though Saginaw Bay does not feature extensive natural coves, manmade coves could be constructed adjacent and intermittently through coastal wetland regions to intercept and contain floating muck for treatment. After muck is separated from water, it would be dredged and disposed of, and water could be discharged per National Pollution Discharge Elimination System (NPDES) standards ("NPDES Permit Program Basics" n.d. 2015). Specific permitting is required for this action.

The use of jetties or containment booms could be used to direct pelagic muck into impoundments for remediation. The typical use of these structures is to control sediment deposition prior to entry in lagoons and shipyards. This same principal could be applied to redirect waves so that they would push muck and fouled sediments into small bays and coves for removal and treatment. Containment booms also show the potential to redirect muck into impoundments as they act directly on floating particles in the water column.

When redirecting floating muck, a concern of resource managers is moving the problem away from the BCSRA and into private beaches in Saginaw Bay. The practice of using impoundments to control muck allows designated spaces in Saginaw Bay to be utilized in the removal of muck and dampens this concern. However, modification of coastal wetlands in The Great Lakes and the Saginaw Bay watershed can be complex. As such, extensive permitting is required.

Permitting for the construction of impoundments and discharge of water in the Great Lakes

Wetlands serve an important role to the ecosystem with which they are connected. Wetlands filter and hold water, purifying it of toxicants and regulating levels in local rivers, streams, and tributaries. Due to their important role, permitting for the construction of impoundments using designated wetland areas can be difficult. Wetlands are protected under part 303, National Resources and Environmental Protection Act (NREPA), 1994, PA 451 ("Wetland Permits" n.d. 2015). Permits are required to engage in activities such as adding fill material, dredging, and removing sediment, and draining surface water. Constructing impoundments would require dredging and the removal of sediments from coastal wetlands to allow an influx of water from Saginaw Bay. As such, wetland permitting will be required for the construction of impoundments.

Approval of permits for wetland construction are dependent on the Department of Environmental Quality's (DEQ) evaluation of the proposed project. Justification will be assessed based on observed compliance with criteria in 303, NREPA, 1994, PA 451. To address these criteria, applicants must show efforts to avoid impacting wetland sites, or justify the credibility of actions and propose wetland replacement strategies ("Wetland Permits" n.d. 2015). The DEQ may approve, request revisions, or deny the proposal. Wetland regulations grants the DEQ authority to determine the impact of activities and credibly halt projects that aren't within state guidelines ("Wetland Permits" n.d. 2015). The DEQ and United States Army Corps of Engineers (ACOE) have established a joint permitting process for areas which have both state and federal jurisdiction. The Michigan Water Resources Division (WRD) determines whether this is appropriate and contacts the applicant to adjust submissions accordingly ("Wetland Permits" n.d. 2015). Permits are also required to discharge water that has been separated from muck and fouled sediments back into Saginaw Bay. Discharge permits are issued through the DEQ and are called National Pollution Discharge Elimination System (NPDES) permits ("NPDES Permit Program Basics" n.d. 2015). This process was thoroughly addressed above.

In addition to wetland and discharge permitting through state and federal agencies, the construction of impoundments may alter local river floodplains and influence groundwater discharge in the region. As such, impoundment construction may also have to address part 31 of the water resources protection through NREPA, PA 451 of 1994. If the construction of impoundments affects Great Lakes bottomlands, permitting should also address part 325 of NREPA, PA 451 of 1994.

Short term costs in the construction of impoundments for muck control

The short-term costs in the construction of impoundments to retain floating muck may be significant. Extensive excavation equipment and machinery operators are required to safely dredge impoundments, and transport dredged sediment:

- Renting/buying excavation equipment to dredge impoundments.
- Hiring licensed machinery operators for the dredging of impoundments.
- Permitting costs.
- Supply costs

Long term costs in the maintenance of impoundments for muck control

The long-term costs in the operation and maintenance of impoundments will be less than initial construction costs. However, these costs will still require periodic large equipment rentals and hiring of trained staff to attend to maintenance and general operation of impoundments. Routine operations at impoundments might include containment boom operation, jetty maintenance, muck removal, assessment, and discharge of water back into Saginaw Bay:

- Containment boom operation.
- Jetty maintenance.
- Equipment used in the handling of dredged sediments. This may include sand drying beds, and equipment used to separate water from sediment.
- Trained staff and excavation equipment operators.
- Supply costs.

1.6 Altering agricultural practices in the Saginaw Bay Watershed

Introduction to altering agricultural practices in Saginaw Bay Watershed

As with many coastal regions in the United States, the Saginaw Bay Watershed is subjected to the negative impacts of anthropogenic stress. A primary stressor known to this region is increased nutrient deposition resulting from local farms situated in the Saginaw Bay watershed. Elevated phosphorus levels have been a persistent issue in Saginaw Bay as nonpoint nutrient pulses are deposited from farmland into neighboring rivers and eventually, inner Saginaw Bay. Phosphorus is the principal nutrient consumed by aquatic plants and algae, the primary constituents of nuisance muck in the BCSRA (Stow et al. 2013). It has been a long-term goal for resource and park managers to reduce phosphorus loading in Saginaw Bay and the BCSRA, as such altering agricultural practices in the Saginaw Bay Watershed region is suggested.

In a National Center for Coastal and Ocean Science (NCCOS) funded research project, the long-term effects of multiple stressors in Saginaw Bay were assessed by a multi-disciplinary group of scientists working through the National Oceanic and Atmospheric Administration Great Lakes Research Laboratory (NOAA-GLERL). One of the many conclusions through the course of this diverse study is that total phosphorus goals set in place with the 1987 supplement (Annex 3) of the 1978 Great Lakes Water Quality Agreement (GLWQA) of 440 metric tons per year and 0.015 mg/L have not been met (Stow et al. 2013). Additionally, the impact of phosphorus deposition in Saginaw Bay may be greater than ever before due to the invasion and establishment of invasive species such as zebra and quagga (*Dreissenid*) mussels. These invasive mussels are voracious filter feeders that rapidly remove green algae from the water column allowing for greater light penetration which promotes the proliferation of benthic and toxic blue-green algae which may bloom late into the summer season (Stow et al. 2013). It should be noted that these phosphorus targets are currently interim targets, as the US and Canada have committed to review and update these targets under the renewed 2012 GLWQA. In addition, it is important to note that these interim targets (440 metric tons per year and 0.015 mg/L) were established in the 1980's prior to the zebra and quagga mussel invasion. Therefore, update phosphorus targets will need to consider current ecological conditions while continuing to support Saginaw Bay's productive fishery. Though phosphorus has been a persistent problem in Saginaw Bay, there have been significant improvements over time. In the late 1970s, the Saginaw River alone was responsible for depositing almost two metric tons a day into the bay. This was the most significant phosphorus deposit into a Great Lake from any river in the Great Lakes basin. During this same era, total phosphorus concentration rose to nearly 0.050 mg/L, over three times higher than the current target (U.S. Environmental Protection Agency 2006) (Stow et al. 2013). Though annual total phosphorus concentrations vary from year to year, there have been significant reductions since the late 1970s (U.S. Environmental Protection Agency 2006).

Increasing limitations on agricultural phosphorus and nutrient loading would be beneficial to reducing nuisance muck deposition on Saginaw Bay's beaches. This alteration in agricultural practices when coupled with enhanced phosphorus removal protocols would help combat nuisance muck at its source, primary productivity. In addition to greater control over agricultural nutrient loading, and improved phosphorus removal, continued education programs and regular meetings within the agricultural community should be instated to keep the agricultural community informed of Best Management Practices (BMPs) and Generally Accepted Agricultural Management Practices (GAAMPs).

A closer look at alternative agricultural options

Phosphorus deposition due to nutrient loading in the Saginaw Bay Watershed has numerous sources. Though nutrient loading from point sources such as wastewater treatment facilities, combined sewer overflows (CSOs), and industrial discharge may be easy to regulate, nonpoint nutrient discharges can be challenging to pinpoint. Nonpoint nutrient deposition as a byproduct of agribusiness such as livestock waste and fertilizer, coupled with urban runoff and septic tanks are significant contributors to increased phosphorus in Saginaw Bay.

There have been several measures to control phosphorus deposition in the Saginaw Bay Watershed over the past four decades. In 1970's the State of Michigan enacted a phosphorus limitation on all cleaning agents (1971) and household laundry detergents (1977). In 2010 and 2012, the State of Michigan restricted the phosphorus content in dishwasher detergent and banned the use of phosphorus in turf grass fertilizers for most domestic and commercial uses (excluding agricultural uses), respectively. In addition, DEQ issued NPDES permits include phosphorus limits to prevent nutrients from stimulating nuisance growths of aquatic plants and algae that became, or that might become, injurious to designated uses. However, even with these restrictions, phosphorus loading is still an issue in the Saginaw Bay Watershed and the 1987 GLWQA phosphorus limits have yet to be met (Stow et al. 2013).

Increased nutrient and pesticide management, improved erosion and sediment control, controlled animal feeding and grazing operations, and increased irrigation and water management (U.S. Environmental Protection Agency 2006) will be needed to help further reduce phosphorus loading to Saginaw Bay.

.

Best Management Practices (BMPs) and Generally Accepted Agricultural Management Practices (GAAMPs)

Continuing education for the Michigan agricultural community is essential to controlling nutrient deposition in the Saginaw Bay Watershed. There is extensive documentation and reference material regarding fertilizer Best Management Practices (BMPs) on the national level, and the Michigan Department of Environmental Quality (DEQ) is currently developing documents tailored to local Michigan Farmers.

Agricultural BMPs describe methods that the agricultural community can use to reduce usage of pesticides, fertilizers, and other potential environmental contaminants. There are many different types of BMPs including cover crops, conservation tillage, and buffer strips, . The Michigan Department of Agriculture and Rural Development (MDARD) has issued a document outlining Generally Acceptable Agricultural Management Practices (GAAMPs) as a reference for agricultural producers.

The GAAMP document issued from MDARD explicitly discusses nutrient utilization and fertilization practices in Michigan. This document describes on-farm fertilizer storage and containment as well as fertilization practices for land application. Fertilizer recommendations are addressed on a by site basis and phosphorus and nitrogen management practices are also discussed. Although fertilization and irrigation practices for container grown plants are discussed, the document fails to discuss runoff prevention and maintenance as it relates to land use. However, the agricultural production BMP document may address these issues when released.

1.6 Relaxing of state and federal regulations

Introduction to the relaxing of state and federal regulations

One motivation behind the relaxing of state regulations is to create large sand beaches at the BCSRA in Saginaw Bay. This is attractive to local residents and businesses as large, pristine beaches would increase regional and national beach visitation and promote a tourist economy in and around the BCSRA. To accomplish this, the BCSRA's coastal wetlands would have to be filled and reestablished elsewhere in the Saginaw Bay Watershed.

Though this issue does not directly deal with nuisance muck at the BCSRA, it is related. Coastal wetlands act as filters for nutrients loads and contaminants in the region, and reducing them would likely increase the muck issue if agricultural nutrient loading isn't first resolved. Relaxing regulations on beach grooming, wetlands and Great Lake bottomlands might make this management option viable.

Relaxing shoreline management regulations

To engage in shoreline management activities, other than beach grooming below the ordinary high water mark (OWHM) and above the water's edge, state and federal permitting are required. This includes dredging, filling, and mechanical removal of vegetation in coastal and inland wetlands. Dredging activities below the water's edge in the Great Lakes also requires state and federal permitting. Wetlands are regulated under Part 303 and Part 325 of the National Resources and Environmental Protection Act 1994, PA 451 ("Great Lakes Shoreline Management." Garwood 2015).

Relaxing wetland regulations

State and federal permitting are required for activities in regulated wetlands to deposit fill material and dredge or remove soil under the authority of Part 303 of the NREPA 1994, PA 451 as amended. Permitting is also required to engage in construction projects, to operate and develop in a wetland, and to maintain a wetland for any purpose. Permits are required to remove water from a wetland for any reason.

The Michigan Department of Environmental Quality (DEQ) makes determinations on permits based on whether the permit is in the public interest, is within the confines of law, supports beneficial activity, does not interrupt aquatic processes and effect wildlife, or has no other alternative to achieve project goals (i.e. could be done elsewhere) ("State and Federal Wetlands Regulations." n.d. 2015).

Relaxing Great Lakes bottomlands regulations

The Michigan DEQ Water Resources Division (WRD) is the governing body responsible for the issuance of state permits relating to Great Lakes bottomlands under the authority of Part 325 of the NREPA 1994, PA 451 as amended. The purpose of permits issued under this regulation is to protect Great Lakes bottomlands as defined by all areas lying beneath the OHWM.

Great Lakes bottomlands state permitting is required for any activities that dredge, fill, modify, construct, enlarge or extend structures into Great Lakes waters. Permitting is also required for activities which occurring between the OHWM and water’s edge ("Great Lakes Submerged Lands Permit (Part 325)" n.d. 2014).

Conclusion

In reviewing beach maintenance practices implemented by the BCSRA as compared to other Great Lakes beaches there are few differences. The BCSRA has taken an active role in maintaining shoreline deposition. This has included manual removal of macrophytes as they wash ashore, hand and landscape raking. This has resulted in improved beach aesthetic which will likely be reflected in beach tourism and attendance. Some beaches have gone beyond this by using beach cleaning machines, beach curtains and sand fences, but it has required significant investment. Unfortunately, most of these strategies are palliative, and therefore only work for a short period, in that they address only the symptoms without controlling the many sources of nuisance muck problems in Saginaw Bay. Ultimately, beach maintenance has improved at the BCSRA in recent times.

References

"Contaminated Sediments Program." EPA. Environmental Protection Agency, 26 June 2012. Web. 20 July 2015.

"Great Lakes Submerged Lands Permit (Part 325)." State License Search. 1 July 2014. Web. 31 July 2015.

"Gunderboom Technology and Projects Overview." Ed. Southeast Operations. Web. 28 July 2015.

"Marina Construction Permits." DEQ. Web. 28 July 2015.

"MuckSuckers - Making Ponds Healthy." MuckSuckers. Web. 23 July 2015.
"NPDES Permit Program Basics." NPDES Permit Program Basics. 19 June 2015. Web. 23 July 2015.

"Permits for Structures or Work in or Affecting Navigable Waters of the United States." Web. 28 July 2015.

"Section 404 Permit Program." EPA. Environmental Protection Agency, 3 Mar. 2016. Web. 18 Aug. 2016.

"Spill Containment Methods | Response.restoration.noaa.gov." Spill Containment Methods | Response.restoration.noaa.gov. 27 July 2015. Web. 28 July 2015.

"State and Federal Wetlands Regulations." DEQ. Web. 31 July 2015.

"ThickTech™." ThickTech™. 2015. Web. 23 July 2015.
“Fundamentals and Case Studies for Retrofitting Wastewater Treatment Systems for Phosphorus Removal”. 2007. Presentation.

Barnard, W.D., and T.D. Hand. 1978. "Treatment of Contaminated Dredged Material," Technical

Dugan, J., Hubbard, D., Page, H., Schimel, J. 2011. Marine macrophyte wrack inputs and dissolved nutrients in beach sands. Estuaries and Coasts, 34(4), 839-850.

Dugan, J.E., and D.M. Hubbard. 2009. Loss of Coastal Strand Habitat in Southern California: The Role of Beach Grooming. Estuaries and Coasts. 33(1):67-77.

Facilities." Great Lakes Dredging Team. Great Lakes Commission, 1996. Web. 18 Aug. 2016.Work, P.A., F.

Fehrenbacher, and G. Voulgaris. 2004. Nearshore Impacts of Dredging for Beach Nourishment. Journal of Waterway, Port, Coastal and Ocean Engineering. 130:303-311.

Francoeur, S.N., K.P. Winslow, D. Miller, C.A. Stow, Y.K. Cha, and S.D. Peacor. 2014. Spatial and temporal patterns of macroscopic benthic primary producers in Saginaw Bay, Lake Huron. Journal of Great Lakes Research. 40:53-63.

Francoeur, S.N., K.P. Winslow, D. Miller, C.A. Stow, Y.K. Cha, and S.D. Peacor. 2014. Spatial and temporal patterns of macroscopic benthic primary producers in Saginaw Bay, Lake Huron. Journal of Great Lakes Research. 40:53-63.

Garwood, A. (n.d.). You are Here, MDEQ Water, Great Lakes. Retrieved July 13, 2015.

Garwood, Anne. "Great Lakes Shoreline Management." DEQ. Web. 31 July 2015.

Hickson, R.E., and F.W. Rodolf. 1950. Design and Construction of Jetties. Coastal Engineering proceedings. 1(26): 227-245

International Association of Dredging Companies. Facts about Confined Disposal Sites. Netherlands: International Association of Dredging Companies, 2010. Print.

Jones, A., T. Sclacher, J. Dugan, M. Lastra, D. Schoeman, A. McLachlan, and F. Scapini. Sandy Beach Ecosystems: Vulnerability, Resilience and Management. 17th NSW Coastal Conference 2008. Wollongong, Australia.

Kart, J. (2012, July 19). Army Corps: Federal Beach Grooming Permits Still Required. Retrieved July 14, 2015.

Kelly, J.F. 2014. Effects of human activities (raking, scraping, off-road vehicles) and natural resource protections on the spatial distribution of beach vegetation and related shoreline features in New Jersey. J Coast Conserv. 18:383-398.

Kinzelman J.L., R.L. Whitman, M.N. Byappanahalli, E.K. Jackson, and R.C. Bagley. 2002. Evaluation of Beach Grooming Techniques on Escherichia coli Densities in Foreshore Sands at North Beach, Racine, WI. Great Lakes Beach Conference 2002. Chicago, IL.

Michigan Department of Environmental Quality. 2013. Dredge Sediment Review. Department of Environmental Quality Policy and Procedure. MDEQ Publication Number 09-018. Lansing, Michigan.

Report DS-78-14, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Santaniello, Neil. "Removing a Blanket of Muck." Tribune digital-sunsentinel. 23 May 2004. Web. 23 July 2015.

Seabergh, W. C., Z. Demirbilek, and L. Lin. 2008. Guidelines Based on Physical, Numerical Modeling Studies for Jetty Spur Design at Coastal Inlets. International Journal for Ecology and Development. 11:4-19.

Stow, C. and T. Hook. 2013. Saginaw Bay Multiple Stressors Report: NOAA Technical Memorandum GLERL-160. Ann Arbor, Michigan. National Atmospheric National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory.

Thorp, Steve. "Case Study: U.S. Great Lakes Dredging and Confined Disposal

U.S. Environmental Protection Agency. 2006. Fact Sheet - Phosphorus in Saginaw Bay, have we met the target? Retrieved 29 July 2015.

Walkington, Terry. "Removal and Potential Muck Removal and Disposal Methods Disposal Methods." 5 May 2009. Web. 23 July 2015.

Appendix 5-A: Past management actions in the BCSRA, Saginaw Bay, Lake Huron

2.1. **Statewide phosphorus bans**

2.1.1. **Saginaw Bay phosphorus control activities**

2.1.1.1. Statewide phosphorus product bans

2.1.1.2. Statewide water quality based effluent limits for phosphorus

2.1.1.3. Combined Sewer Overflow

2.1.1.4. Concentrated Animal Feeding Operation (CAFO) permits

2.1.1.5. Michigan Agriculture Environmental Assurance Program (MAEAP)

2.1.1.6. Conservation Reserve Enhancement Program (CREP)

2.1.1.7. Grant projects addressing phosphorus/nutrients in Saginaw Bay

2.1.1.7.1. Clean Michigan Initiative and Section 319 funding 2005-2015

2.1.1.7.2. Great Lakes Restoration Initiative (GLRI) funding 2010-2014

2.1.1.7.3. Great Lakes Restoration Initiative (GLRI) funding 2015

2.1.1.7.4. Other funding

2.1.1.7.5. Totals for the Grants Mentioned Above 2005 – 2015

2.2. Farm Bill programs for habitat and wildlife protection

2.2.1.2010

2.2.1.1. Shiawassee watershed

2.2.1.2. Pigeon-Wiscoggin watershed

2.2.1.3. Au Gres-Rifle watershed

2.2.1.4. Flint watershed

2.2.2.2011

2.2.2.1. Kawkawlin-Pine watershed

2.2.2.2. Cass watershed

2.2.2.3. Pine watershed

2.2.2.4. Tittabawassee watershed

2.2.2.5. Shiawasee watershed

2.2.2.6. Pigeon-Wiscoggin watershed

2.2.2.7. Au Gres-Rifle watershed

2.2.3.2012

2.2.3.1. Flint watershed

2.2.3.2. Au Gres-Rifle watershed

2.2.3.3. Pigeon-Wiscoggin watershed

2.2.3.4. Shiawassee watershed

Past management actions in the BCSRA, Saginaw Bay, Lake Huron

2.1. **Statewide phosphorus bans**

Since the mid-twentieth century, state and federal government have proposed legislation to try and maintain a clean coastline and waterways. State and federal regulations have been in place for decades to control point and nonpoint pollution from entering aquatic systems. Federal and state legislation such as the Clean Water Act (CWA) have limited discharge through actions such as the National Pollution Discharge Elimination System (NPDES) and supported remediation programs and wastewater treatment upgrades in the Saginaw Bay Watershed. Recently, amended legislation has centered on the control of phosphorus released into the watershed.

Phosphorus is a principal nutrient utilized by aquatic plants and algae. In fact, productivity in aquatic ecosystems is considered phosphorus limited. As such, control of phosphorus can be viewed as a proxy for controlling productivity. In order to control productivity in Saginaw Bay, several phosphorus control activities have been established.

2.1.1. **Saginaw Bay phosphorus control activities**

2.1.1.1. **Statewide phosphorus Product Bans**

- In 1971 Michigan enacted a phosphorus limitation of 8.7% by weight on all cleaning agents.
- Michigan's phosphorus detergent ban was implemented in 1977, restricting the phosphorus content of household laundry detergents to no greater than 0.5% by weight.
- In July 2010 Michigan restricted the phosphorus content of dishwasher detergent to no greater than 0.5% by weight.
- Beginning on January 1, 2012, Michigan banned the use of phosphorus in turf grass fertilizers for most domestic and commercial uses. This ban does not apply to agricultural use of fertilizer containing phosphorus and has several exceptions for use on turf grass.

2.1.1.2. **Statewide water quality based effluent limits for phosphorus**

- In 1973 Michigan adopted state water quality standards, which included a numerical standard of 1 milligram per liter (mg/l) for all discharges to control excess phosphorus entering the Great Lakes, and a narrative standard to limit, as necessary, nutrients that stimulated growths of aquatic plants and algae that might become injurious to designated uses.
- Phosphorus limits less than 1 mg/l were included in National Pollutant Discharge Elimination System (NPDES) permits using the narrative standard to prevent nutrients from stimulating nuisance growths of aquatic plants and algae that became, or that might become, injurious to designated uses.

2.1.1.3. **Combined sewer overflow (CSO)**

- Between 1972 and 1988 Clean Water Act programs provided over $500 million to communities in the Saginaw Bay watershed to upgrade Wastewater Treatment Plants (WWTP) (MDNR 1988).
- Using data from the MDEQ State Revolving Fund, Public Sector Consultants estimated that between 1991 and 2011 an additional $330 million was invested by municipalities in order to correct CSOs and upgrade WWTPs within the watershed (Public Sector Consultants 2012)
- At this time, untreated CSOs have been eliminated from the Saginaw Bay watershed largely due to investments in infrastructure and upgrades to WWTP,

including retention treatment basins. Discharges from retention treatment basins have permit limits set by the MDEQ and must meet water quality standards.

2.1.1.4. Concentrated Animal Feeding Operation (CAFO) permits

- There are approximately 60 CAFOs in the Saginaw Bay watershed that are permitted under Michigan's NPDES CAFO permit.
- The MDEQ's CAFO permits contain requirements for the proper management of manure and wastewater.
- The permits are designed to minimize nutrient releases from production areas and land application areas and, instead, ensure utilization of those nutrients for beneficial use by growing crops.
- The permits require a Comprehensive Nutrient Management Plan that is a record of the activities taken by the CAFO to comply with the permit and includes recordkeeping to document those activities.
- Some CAFOs have treatment systems that help simplify manure management and further reduce nutrient runoff risks.

2.1.1.5. Michigan Agriculture Environmental Assurance Program (MAEAP)

- The mission of the MAEAP is to promote a voluntary, proactive environmental assurance program targeted to the agricultural industry, which ensures producers are engaged in cost-effective pollution prevention practices and are in compliance with environmental regulations.
- The MAEAP includes farmer education, on-farm risk assessment, and third party audit inspections. There are three primary systems of MAEAP: livestock, farmstead, and cropping.
- As of September 2014, MDARD verified 404 farmlands under the MAEAP program within the Saginaw Bay watershed. (Brown, Elaine)

2.1.1.6. Conservation Reserve Enhancement Program

- The purpose of the CREP is to reduce sediment and phosphorus loadings through the implementation of the following agricultural practices: filter strips, field windbreaks, wetland restoration, and riparian forest buffers.
- The Saginaw Bay watershed is an eligible and priority area for CREP
- As of May 2015, the Saginaw Bay watershed had over 53,927 acres enrolled in the CREP. (Hines, Patricia)

2.1.1.7. Grant projects addressing phosphorus/nutrients in Saginaw Bay

2.1.1.7.1. Clean Michigan Initiative and Section 319 funding 2005 – 2015

- Approximately 14 grant projects
- Implemented ~570 BMPs (e.g. no-till, cover crop, filter strips, permanent easements, etc.) within the Saginaw Bay Watershed. These BMPs are estimated to have reduced the discharge of:
    - ~84,700 tons of sediment per year

  - ~102,900 pounds of phosphorus per year
  - ~207,500 pounds of nitrogen per year
- Grant funds for these BMPs: ~$6.5 million

2.1.1.7.2. **Great Lakes Restoration Initiative Funding 2010 - 2014**

- Approximately 45 projects funded
- As a result of these projects, approximately 52,900 acres have been enrolled into conservation practices (e.g. residue management practices, grass waterways, filter strips, etc.) to reduce the discharge of nutrients within the Saginaw Bay watershed. It is estimated that these conservation practices will reduce the discharge of:
  - ~42,000 tons of sediment per year
  - ~111,100 pounds of phosphorus per year
  - ~635,000 pounds of nitrogen per year (Youngstrum, Paul)
- Grant funds: ~$18.3 million

2.1.1.7.3. **Great Lakes Restoration Initiative Funding 2015**

- In 2015, The Nature Conservancy was awarded GLRI funding for a project that has a goal of enrolling approximately 9,000 acres into new conservation practices (e.g. tillage, cover crops, drainage water management, etc.). This project is offering payment based on tons of sediment removed instead of on the amount of acreage enrolled in conservation practices. Under this payment program a landowner with a higher risk of sediment runoff stands to receive larger payments for installing conservation practices than a landowner that has a lower sediment runoff risk. Therefore, it is anticipated that landowners with higher sediment runoff risks will be more attracted to this program and will result in higher load reduction per dollar spent on new conservation practices. If the acreage goal is reached and if higher risk landowners take advantage of this program, it is predicted that these new conservation practice will reduce the discharge of:
  - ~10,350 tons of sediment per year
  - ~8,000 pounds of phosphorus per year
  - Anticipated load reduction estimates for nitrogen are not available at this time (Fales, Mary)
- Grant funds: ~$2.5 million

2.1.1.7.4 **Other funding sources**

- Regional Conservation Partnership Program (RCPP) Funds 2015
  - In 2015, The Nature Conservancy was awarded RCPP funding for a project that has a goal of enrolling 25,500 acres into new conservation practices (e.g. cover crops, filter strips, reduced tillage (no till, mulch till,

or strip till), etc.) by 2019. If this acreage goal is reached, it is predicted that these new conservation practices will reduce the discharge of:

    - ~2,800 tons of sediment per year
    - ~18,500 pounds of phosphorus per year
    - ~197,400 pounds of nitrogen per year (Fales, Mary)

  - Grant Funds: ~$10 million

2.1.1.7.5. **Totals for the Grants Mentioned Above 2005 – 2015**

- Approximately 61 projects received grant funds to reduce phosphorous/nutrient loadings within the Saginaw Bay watershed. Cumulatively, these projects are estimated to reduce the discharge of:
  - ~139,850 tons of sediment per year
  - ~240,500 pounds of phosphorus per year
  - ~1,039,900 pounds of nitrogen per year (note: estimated nitrogen load reduction were not available for TNC's 2015 GLRI grant)
- Total grant funds: ~$37.3 million

References

Brown, Elaine, 2015. Personal Communications 5/21/15.

Fales, Mary, 2015. Personal Communications 7/1/15.

Hines, Patricia, 2015. Personal Communications 5/21/15.

Michigan Department of Natural Resources, 1988. Remedial action plan for Saginaw River and bay areas of concern. Lansing, Michigan. Final report prepared by the Michigan Department of Natural Resources (588 pp., Last accessed on April 14, 2015, at: http://www.michigan.gov/documents/deq/1988_Saginaw_RAP_441130_7.pdf?20150414131114

Public Sector Consultants, 2012. Saginaw Bay watershed and area of concern. Lansing, Michigan. Final report submitted to Michigan State University, Planning and Zoning Center, and the Michigan Department of Environmental Quality, Office of the Great Lakes (7 pp., Last accessed on April 14, 2015, at: http://www.pscinc.com/LinkClick.aspx?fileticket=Hi_PFZU-xOI%3D&tabid=65

Selzer, M.D., Joldersma, B., Beard, J., 2013. A reflection on restoration progress in Saginaw Bay watershed. Journal of Great Lakes Research Vol. 40 (Supplement 1). pp 192-200

2.2 Farm Bill programs for habitat and wildlife protection

In 2010, the USDA Natural Resources Conservation Service (NRCS) implemented Farm Bill Programs for Habitat and Wildlife Protection. These programs reduced agricultural nonpoint source loading and included funding for terrestrial invasive species control.

2.2.1 2010

2.2.1.1 Shiawassee watershed

In the Shiawassee watershed, USDA the Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080203 Shiawassee watershed

From 5/20/2010 to 9/30/2014

USDA GLRI amount $1,135,556

2.2.1.2 **Pigeon-Wiscoggin watershed**

In the Pigeon-Wiscoggin watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080103 Pigeon-Wiscoggin watershed
From 5/20/2010 to 9/30/2014
USDA GLRI amount $1,338,193

2.2.1.3 **Au Gres-Rifle watershed**

In the Au Gres-Rifle watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080101 Au Greg-Rifle watershed
From 5/20/2010 to 9/30/2014
USDA GLRI amount $429,955

2.2.1.4 **Flint watershed**

In the Flint watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080204 Flint watershed
From 5/20/2010 to 9/30/2014
USDA GLRI amount $52,683

2.2.2 2011

2.2.2.1 Kawkawlin-Pine watershed

In the Kawkawlin-Pine watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080102 Kawkawlin-Pine watershed
From 5/20/2011 to 9/30/2014
USDA GLRI amount $28,247

2.2.2.2 Cass watershed

In the Cass watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080205 Cass watershed
From 5/20/2011 to 9/30/2014
USDA GLRI amount $384,854

2.2.2.3 Pine watershed

In the Pine watershed USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080202 Pine watershed
From 5/20/2011 to 9/30/2014
USDA GLRI amount $4,353

2.2.2.4 Tittabawassee watershed

In the Tittabawssee watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080201 Tittabawassee watershed
From 5/20/2011 to 9/30/2014
USDA GLRI amount $5,079

2.2.2.5 **Shiawassee watershed**

In the Shiawassee watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080203 Shiawassee watershed
From 5/20/2011 to 9/30/2014
USDA GLRI amount $785,872

2.2.2.6 **Pigeon-Wiscoggin watershed**

In the Pigeon-Wiscoggin watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080103 Pigeon-Wiscoggin watershed
From 5/20/2011 to 9/30/2014
USDA GLRI amount $870,480

2.2.2.7 **Au Gres-Rifle watershed**

In the Au Gres-Rifle watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080101 Au Greg-Rifle watershed

From 5/20/2011 to 9/30/2014
USDA GLRI amount $92,651

2.2.3 2012

2.2.3.1 Flint watershed

In the Flint watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Environmental Quality Incentives Program (EQIP) to implement conservation practices that reduce soil erosion and phosphorus runoff to waters of the Saginaw River watersheds in the Great Lakes Basin.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080204 Flint watershed
From 5/18/2012 to 9/30/2014
USDA GLRI amount $1,424,840

In the Flint watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080204 Flint watershed
From 5/18/2012 to 9/30/2014
USDA GLRI amount $287,572

2.2.3.2 Au Gres-Rifle watershed

In the Au Gres-Rifle watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service
HUC 04080101 Au Gres-Rifle watershed
From 5/18/2012 to 9/30/2014
USDA GLRI amount $19,394

2.2.3.3 Pigeon-Wiscoggin watershed

In the Pigeon-Wiscoggin watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service
HUC 04080103 Pigeon-Wiscoggin watershed
From 5/18/2012 to 9/30/2014
USDA GLRI amount $316,762

2.2.3.4 **Shiawassee watershed**

In the Shiawassee watershed, USDA Natural Resources Conservation Service (NRCS) will implement work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service
HUC 04080203 Shiawassee watershed
From 5/18/2012 to 9/30/2014
USDA GLRI amount $354,988

In the Shiawassee watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Environmental Quality Incentives Program (EQIP) to implement conservation practices that reduce soil erosion and phosphorus runoff to waters of the Saginaw River watersheds in the Great Lakes Basin.

Department of Agriculture - Natural Resources Conservation Service
HUC 04080203 Shiawassee watershed
From 5/18/2012 to 9/30/2014
USDA GLRI amount $467,400

2.2.3.5 **Pine watershed**

In the Pine watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species. HUC 04080202 Pine watershed

Department of Agriculture - Natural Resources Conservation Service
HUC 04080202 Pine watershed
From 5/18/2012 to 9/30/2014
USDA GLRI amount $36,616

2.2.3.6 **Cass watershed**

In the Cass watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service
HUC 04080205 Cass watershed
From 5/18/2012 to 9/30/2014
USDA GLRI amount $36,616

2.2.3.7 **Tittabawassee watershed**

In the Tittabawssee watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service
HUC 04080201 Tittabawssee watershed

From 5/18/2012 to 9/30/2014
USDA GLRI amount $42,670

2.2.3.8 **Kawkawlin-Pine watershed**

In the Kawkawlin-Pine watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service
HUC 04080102 Kawkawlin-Pine watershed
From 5/18/2012 to 9/30/2014
USDA GLRI amount $65,789

2.2.4 **2013**

2.2.4.1 **Pigeon-Wiscoggin watershed**

In the Pigeon-Wiscoggin watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Res
HUC 04080103 Pigeon-Wiscoggin watershed
From 7/18/2013 to 9/30/2016
USDA GLRI amount $1,230,090

2.2.4.2 **Kawkawlin-Pine watershed**

In the Kawkawlin-Pine watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080102 Kawkawlin-Pine watershed
From 7/18/2013 to 9/30/2016
USDA GLRI amount $2,114

2.2.4.3 **Shiawasee watershed**

In the Shiawassee watershed, USDA Natural Resources Conservation Service (NRCS) will implement work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080203 Shiawassee watershed
From 7/18/2013 to 9/30/2016
USDA GLRI amount $5,676

In the Shiawassee watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Environmental Quality Incentives Program (EQIP) to implement conservation practices that reduce soil erosion and phosphorus runoff to waters of the Saginaw River watersheds in the Great Lakes Basin. HUC 04080203 Shiawassee watershed

Department of Agriculture - Natural Resources Conservation Service

HUC 04080203 Shiawassee watershed
From 5/15/2013 to 9/30/2016
USDA GLRI amount $238,805

2.2.4.4 **Flint watershed**

In the Flint watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080204 Flint watershed

From 7/18/2013 to 9/30/2016

USDA GLRI amount $57,727

In the Flint watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Environmental Quality Incentives Program (EQIP) to implement conservation practices that reduce soil erosion and phosphorus runoff to waters of the Saginaw River watersheds in the Great Lakes Basin.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080204 Flint watershed

From 5/15/2013 to 9/30/2016

USDA GLRI amount $404,667

2.2.4.5 **Cass watershed**

In the Cass watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080205 Cass watershed

From 7/18/2013 to 9/30/2016

USDA GLRI amount $717,637

Department of Agriculture - Natural Resources Conservation Service

HUC 04080205 Cass watershed

From 6/13/2013 to 9/30/2017

USDA GLRI amount $287,635

2.2.4.6 **Pine watershed**

In the Pine watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080202 Pine watershed

From 7/18/2013 to 9/30/2016

USDA GLRI amount $85,643

2.2.5 **2014**

2.2.5.1. **Au Gres-Rifle watershed**

In the Au Gres-Rifle watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080101 Au Gres-Rifle watershed

From 6/13/2014 to 9/30/2017

USDA GLRI amount $21,139

2.2.5.2. **Flint watershed**

In the Flint watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Environmental Quality Incentives Program (EQIP) to implement conservation practices that reduce soil erosion and phosphorus runoff to waters of the Saginaw River watersheds in the Great Lakes Basin.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080204 Flint watershed

From 6/13/2014 to 9/30/2017

USDA GLRI amount $188,783

Department of Agriculture - Natural Resources Conservation Service

HUC 04080204 Flint watershed

From 6/13/2014 to 9/30/2017

USDA GLRI amount $337,119

2.2.5.3. **Pigeon-Wiscoggin watershed**

In the Pigeon-Wiscoggin watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Res
HUC 04080103 Pigeon-Wiscoggin watershed

From 6/13/2014 to 9/30/2017
USDA GLRI amount $1,003,707

2.2.5.4. **Pine watershed**

In the Pine watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program, Wildlife Habitat Incentives Program, and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080202 Pine watershed

From 6/13/2014 to 9/30/2017

USDA GLRI amount $2,201

2.2.5.5. **Cass watershed**
In the Cass watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080205 Cass watershed

From 6/13/2014 to 9/30/2017

USDA GLRI amount $287,635

2.2.5.6. **Shiawasee watershed**

In the Shiawassee watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Environmental Quality Incentives Program (EQIP) to implement conservation practices that reduce soil erosion and phosphorus runoff to waters of the Saginaw River watersheds in the Great Lakes Basin.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080203 Shiawassee watershed
From 6/13/2014 to 9/30/2017

USDA GLRI amount $452,301

In the Shiawassee watershed, USDA Natural Resources Conservation Service (NRCS) will implement work directly with agricultural producers through its Conservation Technical Assistance Program and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080203 Shiawassee watershed
From 6/13/2014 to 9/30/2017

USDA GLRI amount $67,739

2.2.5.7. **Tittabawasee watershed**

In the Tittabawssee watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080201 Tittabawssee watershed

From 6/13/2014 to 9/30/2017

USDA GLRI amount $49,914

2.2.5.8. **Kawkawlin-Pine watershed**

In the Kawkawlin-Pine watershed, USDA Natural Resources Conservation Service (NRCS) will work directly with agricultural producers through its Conservation Technical Assistance Program and Environmental Quality Incentives Program to implement conservation practices to address habitat and wildlife protection and restoration, reduce soil erosion and nutrient loading; and reduce terrestrial invasive species.

Department of Agriculture - Natural Resources Conservation Service

HUC 04080102 Kawkawlin-Pine watershed

From 6/13/2014 to 9/30/2017

USDA GLRI amount $732,169

2.3. Pigeon River Corridor sediment reduction project

This project consists of design and implementation of best management practices for stream bank stabilization and soil erosion control located within the Pigeon River riparian corridor. Additional best management practices include: incentives for and installation of buffers; wetland restoration; tile outlet repair and construction of a regional sediment basin.

Pigeon River Interagency Drain Drainage Board
From 1/1/2011 to 12/31/2013
EPA GLRI amount $800,000

2.4. Rifle River Watershed Nonpoint Implementation Project

This project will address the two highest pollutants of concern within the Rifle River watershed: sediment and nutrient loading. This will be accomplished by addressing the sources of pollution by implementing agricultural, stream bank, road crossing, storm water and permanent land protection best management practices. In addition, the existing watershed plan will be updated to meet current U.S. Environmental Protection Agency guidelines.

Huron Pines

From 9/1/2010 to 8/31/2013

EPA GLRI amount $382,000

2.5. Sediment reduction in the Sebewaing River watershed

The Michigan Department of Agriculture and Rural Development will implement agricultural best management practices to significantly reduce sedimentation and nutrient loss from the Sebewaing River Watershed to the waters of Saginaw Bay. This project will prevent 21,000 tons of sediment, 16 tons of phosphorus, and 33 tons of nitrogen from entering the Sebewaing River, its tributaries, and Saginaw Bay each year.

Michigan Department of Agriculture

From 8/1/2011 to 7/31/2014
EPA GLRI amount $422,209

2.6. Sediment reduction in the Swartz Creek watershed

The Michigan Department of Agriculture and Rural Development will implement agricultural best management practices to significantly reduce sedimentation and nutrient loss from the Swartz Creek Watershed to the waters of the Flint River and Saginaw Bay. This project will prevent 5,084 tons of sediment, 4 tons of phosphorus, and 8 tons of nitrogen from entering Swartz Creek, the Flint River, and Saginaw Bay each year.

Michigan Department of Agriculture

From 8/1/2011 to 7/31/2014
EPA GLRI amount $376,517

2.7. Targeted Phosphorus Reduction in the Pigeon River Watershed

The Michigan Department of Environmental Quality (MDEQ) will reduce phosphorus loads from the Pigeon River Watershed to address Saginaw Bay’s designated use impairment. MDEQ will use agricultural best management practices at targeted sites in the Lower Pigeon, West Branch Drain and Upper Pigeon sub-watersheds, which will reduce phosphorus loads by over 5,000 pounds per year.

Michigan Department of Environmental Quality
From 10/1/2011 to 9/30/2014
EPA GLRI amount $890,735

2.8. Kawkawlin River Targeted Phosphorus and E. Coli Reduction

The Kawkawlin River watershed is located in the western coastal basin of Saginaw Bay. This project will implement best management practices (BMPs) identified in the Kawkawlin River Watershed Management Plan. The BMPs include installing six miles of agricultural buffers, 1,700 acres of wind barriers, 1,000 feet of livestock exclusion fencing, and planting 6,000 acres of cover crops. This project is expected to prevent E. coli, 15,491 lbs of phosphorus (30% of the load reduction goal for the watershed) and 10,921 tons of sediment from reaching Saginaw Bay each year.

Michigan Department of Environmental Quality
From 10/1/2011 to 9/30/2014
EPA GLRI amount $995,204

2.9. **Saginaw Bay Watershed Conservation Partnership**

Saginaw Bay, an embayment of Lake Huron, hosts the largest coastal wetland in Lake Huron and faces numerous water quality challenges, including loss of habitat, excessive nutrients and sediment, and algal blooms. This project will set ecologically relevant implementation goals, track progress using new online tools, and harness the influence of agribusiness as a complementary delivery mechanism in order to reach goals of treating acres with conservation practices through EQIP and restoring acres of wetlands through ACEP by 2019. The partners will track effectiveness using the Great Lakes Watershed Management System to quantify acres implemented and total sediment and nutrients reduced annually while also working with project partners to monitor long-term trends in fish community health.

The Nature Conservancy

2015

USDA Regional Conservation Partnership Program funding amount $10,000,000

The Nature Conservancy will administer a program to reimburse farmers for implementing conservation practices (tillage, cover crops and drainage water management) on 10,000 acres of cropland in the Saginaw Bay watershed. The project will reduce nutrient runoff and soil erosion that impacts Saginaw Bay and Lake Huron.

The Nature Conservancy

2015

EPA GLRI amount $2,258,853

Appendix 5-B. Workshop 1 agenda and stakeholder list.

September 22, 2014

Location: Constitution Hall,
Hale Brake Conference Room,
525 West Allegan Street, **Lansing, MI** 48909-7973

Moving towards a solution:
Identifying management scenarios and public perception for Muck at the Bay City State Recreation Area

WORKSHOP 1 OBJECTIVES

The overall goal of this workshop is to unite expert stakeholder interests and expertise with a scientific assessment of drivers of muck at the Bay City State Recreation Area **to inform policy and management practices.** We have invited a select group of technical experts to assist us in achieving this goal through a sharing of group expertise and experience.

Through this first workshop, you can expect to:

- *Share information* with other key stakeholders (e.g., policy makers, regulatory agencies,) about your organization/program and your role in the management or use of the Bay City State Recreation Area including your priorities, constraints, and needs;
- *Learn* from other stakeholders about their roles, priorities and constraints and how your organization fits within this broader system of stakeholders in the Bay City State Recreation Area;
- *Network*, develop new contacts, and possibly identify new opportunities for collaboration;
- *Develop a greater awareness* of the system surrounding the issues of Muck and human health effects and your organization's place within this system;
- *Participate in identifying opportunities* for reducing uncertainties regarding Muck and for maximizing the effectiveness and efficiency of future management efforts.

WORKSHOP AGENDA

Time	Topic	Speaker
8:45-9:00	Continental Breakfast	
9:00-9:30 AM	Welcoming Remarks and Introductions	Donna Kashian
9:30-9:45	Public Perception Overview	Jason Duvall & Avik Basu
9:45-10:45	Stakeholder feedback: facilitated discussion of preliminary findings from interviews	
10:45-11:00	Break	
11:00-11:15	Model overview	Joe DePinto
11:15-11:45	Stakeholder feedback: recommendations for feasible/potential management scenarios	
11:45-12:15	Stakeholder feedback: Identify your role in the Muck issue; Data Request (Human Health, economic, water quality, stakeholder identification).	Darrin Hunt
12:15-12:30	Closing Remarks	Donna Kashian
12-30-1:00	Lunch Provided	

Thank you for participating and assisting in this endeavor!

Appendix 5-B cont. Stakeholder list.

Organization	Name	Project Coordinator	Agency stakeholder	Local Stakeholder
University of Michigan	Basu, Avik	✓		
Michigan Department of Environmental Quality	Bauer, Charlie		✓	
Bay County Commission	Begick, Vaughn			✓
Michigan Department of Environmental Quality	Briggs, Shannon		✓	
State Representative Bunner	Buda, Mike			✓
University of Michigan	Carman, Jennifer			✓
Bay County Commission	Coonan, Kim			✓
LimnoTech	Depinto, Joe		✓	
Mlive.com	Dodson, Andrew			✓
United States Geological Survey	Duris, Joseph W.		✓	
University of Michigan	Duvall, Jason	✓		
Michigan Department of Natural Resources	Fahlsing, Ray	✓		
Saginaw Bay Watershed Project Director	Fales, Mary			✓
East Michigan Council of Governments	Fitzpatrick, Jane			✓
Eastern Michigan University	Francoer, Steve N.			✓
Michigan State University	Gim Aw, Tiong			✓
Bay County Executive	Hickner, Thomas			✓
Partnership for the Saginaw Bay Watershed	Hill, Brad			✓
Michigan Sea Grant	Hintzen, Katy		✓	
Wayne State University	Hunt, Darrin			✓
Michigan Department of Environmental Quality	Joldersma, Bretton		✓	
Michigan Sea Grant	Joseph-Joshi, Sonia		✓	
Michigan State University	Kaplowitz, Mike	✓		
Saginaw Valley State University	Karpovich, David			✓
Wayne State University	Kashian, Donna	✓		
Michigan Department of Environmental Quality	Keiper, Bill		✓	
Saginaw Bay Watershed Initiative Network	Kelly, Mike			✓
Farm Bureau - Bay County	Kernstock, Bob			✓
Michigan Department of Environmental Quality	Klemans, Diana		✓	
Bay County Commission	Krygier, Ernie			✓
Michigan Department of Natural Resources	Lauinger, George		✓	
Michigan State University	Lupi, Frank	✓		
Farm Bureau- Bay County	Mulders, Mike			✓
Bay County Commission	Ogar, Laura			✓
Great Lakes Observing System	Paige, Kelli		✓	
Michigan Department of Environmental Quality	Riley, John		✓	
Drain Commisioner	Rivet, Joseph			✓
Bay County Drain Commission	Rivet, Joseph			✓
BaySail	Roberts, Shirley			✓

Michigan State University	Rose, Joan			✓
Kawkawlin River Watershed Association	Rowley, Glenn			✓
Great Lakes Bay Convention & Visitor Bureau	Rummel, Annette			✓
Bay County Resident	Rydek, Tom			✓
Michigan Sea Grant	Samples, Amy		✓	
Farm Bureau - Bay County	Schindler, Terry			✓
Great Lakes Bay Regional Convention & Visitors Bureau	Scott, Wendy			✓
Bay Area Chamber of Commerce	Seward, Mike			✓
Partnership for Saginaw Bay Watershed	Smith, Warren			✓
Bay Landscaping	Somalski, Jerry			✓
Bay County Commission	Stamiris, Lynn			✓
Saginaw Bay Water Trail Association	Starkweather, Frank			✓
Kawkawlin River Watershed Association	Staudacher, Jeff			✓
National Oceanic and Atmospheric Administration	Stow, Craig		✓	
Michigan Department of Environmental Quality	Swainston, Amy		✓	
Bay Area Community Foundation	Tenbusch, Jeffery			✓
Bay County Commission	Wallace, Alicia			✓
Friends of Bay City State Recreation Area	Washabaugh, Cathy			✓
Friends of Bay City State Recreation Area	Weiland, Nancy			✓
Partnership for the Saginaw Bay Watershed	Wright, Bill			✓
Michigan Agriculture Environmental Assurance Program	Young, Tom		✓	

Chapter 6: Synthesis

Organic debris referred to as “muck” has been documented in the Saginaw Bay region since the 1960s with additional evidence going back to the 1920s. Muck has environmental, human health, economic and social impacts and as such requires an interdisciplinary, stakeholder engagement process to help inform management options. This project used the Integrated Assessment (IA) approach to understand the muck issue and identify possible solutions for the Bay City State Recreation Area (BCSRA). This IA process engaged a variety of stakeholders including federal, state, and local agencies; universities; Multiple Stressors technical experts; and, the Friends of the BCSRA. Community engagement occurred through the process.

Key outcomes of this project are grouped into four themes:

Environmental Modeling and Human Health Impacts

- Even drastic reductions in external phosphorus loads will not result in complete elimination of Cladophora growth in the inner bay.
- Increased water levels can limit the area extent of Cladophora growth due to light limitation.
- The Saginaw River provides approximately 82% of the TP load to the bay, however other smaller tributaries can have important influences on localized regions near their mouths.

The environmental modeling component demonstrated that even drastic reductions in external phosphorus loads will not result in complete elimination of Cladophora growth in the inner bay, although the peak growth at the mouth of the Saginaw River is reduced significantly. The model also showed that increased water levels can play a role in the amount of Cladophora growth. Deeper waters limit the area that light can penetrate down to the sediments, and therefore remove some viable substrate area for benthic algae growth. Finally, the model was used to assess the relative contribution of the main tributaries to each model grid cell. This analysis demonstrated that while the Saginaw River provides approximately 82% of the total phosphorus load to the bay and dominates the overall nutrient balance, there are areas within the inner bay that are significantly influenced by other smaller tributaries.

In the human health impact review, several regional studies implicated muck as a nonpoint source of fecal indicator bacteria (FIB). *E. coli* and enterococci were highest in algal mats and sediment. Elevated bacteria in shallow waters were related to concentrations of bacteria in the sediment and algal mats. This presence may not be due to recent influx of fecal materials, but may be legacy contamination that persists in sediments and algal mats. Higher concentrations of *E. coli* were found in wetter shoreline wrack, and high concentrations of *E. coli* were released during rinsing experiments, suggesting that loosely attached *E. coli* were abundant. This may contribute to the often-seen spike in FIB following rainfall events. A study in California demonstrated that beach grooming of wrack associated with FIB saw either no change or increase in FIB concentrations, with additional impacts of beach grooming including surf zone turbidity and silicate, phosphate, and dissolved inorganic nitrogen concentrations. The findings suggest that beach grooming for wrack removal is not justified as a microbial pollution remediation strategy.

Economic Impacts

- The data and economic models of beach visitation predicted that the Huron South region (which contains the BCSRA and 41 other beaches) receives just under 7% of the beach visits in the lower peninsula of Michigan and the BCSRA receives about 8% of the predicted trips to its region.
- From the overall data and the modeling results, it was clear that all else equal, beachgoers prefer Great Lakes beaches in other regions, especially beaches on Lake Michigan—beaches in the Huron South region had the lowest baseline visitation of any region.
- Despite the general preference for beaches in other regions, the results suggest that improvements in water quality in the Huron South region would yield significant economic benefits to beachgoers and increase the economic impacts of trips to the region, though the region's beaches would likely remain less popular than the Lake Michigan regions or the Southeast Michigan region.

The economic analysis found that spending by all Michigan beachgoers living in the Lower Peninsula had a total economic impact of direct sales within a region that ranged from $425.87 million to $1.72 billion per season in 2014 dollars. Michigan Central region received the largest amount of total direct sales at $1.72 billion, in contrast to Huron South region (which contains Saginaw Bay) with the lowest total sales at $425.87 million. If half of Great Lakes beaches' water quality in a region are increased by one level (e.g., medium to high quality), compared to the direct sales at status quo, the direct sales increases by 33.52% for Mid-East region (Huron South). Improving water quality leads to more utility increase for beaches with initially higher algae levels than for beaches with initially lower algae levels in Huron North and Lake Michigan. When water quality is degraded by one level, the LP Mid-East region loses $138.76 million total sales.

Public Perception

- Citizens and agencies believe that they disagree about the various causes of beach muck, but both groups rated some causes (i.e., ecosystem factors and nutrient loading) similarly. While citizens did feel wastewater discharges were a stronger contributor, these results suggest a shared understanding about some underlying causes.
- Citizens expressed strong concerns about the negative impact beach muck has on park visitation, local economic activity, community well-being, and aesthetics. While agencies did view these impacts as less important, there was evidence that in some cases agencies do have a deeper appreciation for these concerns than citizens might realize or give agencies credit for.
- With few exceptions, citizens viewed all management strategies more positively in terms of effectiveness and practicality than agency representatives. This discrepancy speaks to the strong desire among citizens to see management action and the uncertain impact of management efforts perceived by agency representatives.

To develop a better understanding of stakeholder perception of the muck (and associated FIB) and state agencies credibility to address the issue, this study interviewed citizens and agency representatives. Citizens indicated that they felt moderately knowledgeable about the muck issue, with a mean score slightly higher than mid-range. The mean knowledge rating of agency representatives was nearly half a point higher than that of citizens. Agencies significantly underestimated the knowledge that citizens felt they had regarding beach muck by more than a full rating point. Although this suggests that the public may be more educated than agencies realize, it is important to remember that citizen knowledge is likely to be quite varied, with some citizens knowing very little and others knowing a good deal more. This situation can create challenges for resource management agencies. Attempts to educate citizens about the basics of beach muck may be appropriate for some audiences, but citizens who feel more knowledgeable may not be interested or receptive to these kinds of efforts—wanting instead to discuss what they feel are more pressing issues, such as management actions.

In order to assess management options, agency representatives and citizens were asked to rate 10 strategies (not at all to extremely). Citizens evaluated all management options as being at least somewhat effective and practical. That said the use of a *Muck Filtering Machine* and *Physical Removal* of muck from the beach were deemed as the two most effective management options by citizens. Citizens seemed to make less significant distinctions about whether certain management options were more practical than others. Agency representatives were much more critical of the effectiveness and practicality of all the proposed management strategies; with only one strategy, *Physical Removal*, receiving a high mean rating for both effectiveness and practicality.

Management Solutions

- Improved beach aesthetics have resulted from manual removal of macrophytes, including hand raking and costly beach cleaning machines, which will likely be reflected in beach tourism and attendance.
- These strategies are palliative and only work for a short period.
- **Recommendation**: Given that beach muck appears to be a historical part of the system and that nutrient reduction most likely won't prevent muck from fouling Saginaw Bay beaches, we recommend diverting resources from beach cleaning efforts that attempt to achieve bare sandy beaches, and instead focusing resources on emphasizing alternative ecological attractions such as the local wetlands.

Most beaches across the Great Lakes manage shoreline deposition on an as needed basis using manual removal, hand and landscape rakes. In extreme conditions, some beaches employ the usage of heavy machinery such as tractors, Cherrington and Barber beach cleaners, and tow away services. To offset costs, most beaches employing extreme measures have partnered with volunteer organizations, share heavy equipment with other state parks, or some combination of the two.

In reviewing beach maintenance practices implemented by the BCSRA as compared to other Great Lakes beaches there are few differences. The BCSRA has taken an active role in maintaining shoreline deposition. This has included manual removal of macrophytes as they wash ashore, with hand and landscape raking. This has resulted in improved beach aesthetic which will likely be reflected in beach tourism and attendance. Some beaches have gone beyond this by using beach cleaning machines, beach curtains and sand fences, but it has required significant investment. Unfortunately, most of these strategies are palliative, and therefore only work for a short period, in that they address only the symptoms without controlling the many sources of nuisance muck problems in Saginaw Bay. Given that beach muck appears to be a historical part of the system and that nutrient reduction most likely won't prevent muck from fouling Saginaw Bay beaches, we recommend diverting resources from beach cleaning efforts that attempt to achieve bare sandy beaches, and instead focusing resources on emphasizing alternative ecological attractions such as the local wetlands. Wetlands provide a host of recreational and educational opportunities such as bird and wildlife viewing that have been utilized by many other areas to provide regional economic benefit (e.g., the Everglades).