Economic Benefits of Reducing Harmful Algal Blooms in Lake Erie

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1.0 EXECUTIVE SUMMARY

The International Joint Commission (IJC) sponsored this study to better understand the socioeconomic and policy implications of Harmful Algal Blooms (HABs) in western Lake Erie. This study is the second phase of an IJC-funded study (Weicksel and Lupi, 2013) and further examines the implications of extensive HAB events like the ones that occurred in 2011 and 2014. The previous study identified many important issues, and quantified some - but not all - of the socioeconomic implications of western Lake Erie HABs.

This project extends that Phase 1 study by further evaluating HAB effects to regional economic welfare including effects to recreation, water withdrawals, tourism, and property values. Results of the Phase I study indicated that western Lake Erie HABs can affect inter-related economic systems over a broad, geographic area, and that little information has been collected to specifically support economic benefit studies. This study has benefited from the previous work conceptually and methodologically, however, the problem of information limitations persists. For example, certain information such as timing and severity of HABs at a micro-level (beach, marina, neighborhood, etc.) as well as short-run responses of people (such as recreators and/or tourists) and markets (rental, hotel, housing, restaurants) to the HABs are not available.

An additional challenge has been that certain responses of people and markets may not result directly from any specific HAB incident. Rather, these responses (termed lagged and halo effects in the Phase 1 report) occur in different places and time periods than HABs, and result from more complex cognitive and economic processes than the comparatively easy to measure (with appropriate data) economic effects that arise from ecological service reductions. As a result of these two factors, it is not currently feasible to quantify the economic effects of HABs using statistically-significant parameters within rigorous econometric models. Not having that capability, this effort relies on available secondary data and studies. To further illustrate possible effects, this information is incorporated by an evaluation of “value at risk,” which employs scenarios and sensitivity analyses to characterize ecological service interruptions and their immediate economic effects. In addition, this study presents a HAB severity index, created for 2011 and 2014 events, that varies by week and county. This construct is used to generate estimates of economic effects for these years; it could also be employed to evaluate future HABs events on Lake Erie. Less immediate (i.e., lagged and halo) effects are discussed and quantified in the context of these effects.

This study is not a marginal analysis of the benefits of reducing HABs by some amount. Rather, it strives to identify the economic benefits of *reductions* in *future* HABs and does so by evaluating the benefits of avoiding a recurrence of certain, previous HAB events. Thus, although the scenarios considered are based on past events (i.e., ex post), these events are considered as they would occur in the future. This ex ante (forward-looking) viewpoint was applied because of its policy relevance. A result of applying this policy-relevant approach is that previous mitigation actions affect whether or not impacts are evaluated. For example, in 2014, HABs resulted in economic damages due to interruption of water services in

This project strives to identify the economic benefits of reductions in future HABs and does so by evaluating the benefits of avoiding a recurrence of certain, previous HAB events. Thus, although the scenarios considered are based on past events (i.e., ex post), these events are considered as they would occur in the future.

Toledo, Ohio, and on Pelee Island, Ontario. In Toledo, the municipal water system was disrupted leading to severe economic effects on households and businesses. The city has since initiated preventative measures, so water services are unlikely to be similarly interrupted in the future due to HABs. Well water on Pelee Island was affected, but there is no indication that steps have been taken to avoid interruption of water services in the future. Consequently, when evaluating the *benefits of future HAB reductions*: a) past damages incurred on Pelee Island are measured, and b) past damages incurred in Toledo are *not* measured, although ongoing expenditures to protect Toledo's water system from HABs are counted.

A summary of the project's findings related to property values, tourism, recreation, and water withdrawals (in U.S. dollars) are outlined below.

- *Property Values:* This study quantified $3.458 billion in residential housing stock that are located on the shore or in the nearshore (within 0.5 mile of the shoreline) of the western basin of Lake Erie. Part of this value is at risk for being impacted by HAB events. Because Lake Erie HABs are unique, it is challenging to identify the degree of these impacts. This effort did not link market prices directly to the 2011 and 2014 HAB events. Even though the impact is unknown, given the value of the nearby stock, HABs causing a 5 percent impact to near-shore values and a 10 percent impact to shoreline properties would result in $242.1 million in property value impacts.

  For another perspective, this study evaluated specific impacts from 2011 and 2014 HAB events by applying a lost property value services approach. This approach identifies economic effects based on interruptions to Lake Erie ecological services. For 2011, this approach estimates lost property value services of $9.781 million for shoreline property owners and $7.087 million for nearshore property owners. For the 2014 HAB event, shoreline property owners are estimated to have lost $10.05 million in property value services, while nearshore owners lost $7.864 million.

> ***This study quantified $3.458 billion in residential housing stock that are located on the shore or within the nearshore (within ½ mile of the shoreline) of the western basin of Lake Erie,that are potentially at risk for being impacted by HAB events. To further get an idea of the scale, a 5 percent impact to near-shore values and a 10 percent impact to shoreline value translates into a total of $242.1 million impact in property values.***

- *Tourism:* Every year, millions of out-of-town trips are taken to counties adjacent to western Lake Erie with billions of dollars in expenditures boosting those communities' economies. Although not all of this is directly related to Lake Erie, and only a portion occurs during prime, potential HAB time periods, it is clear that significant tourism revenue is at risk due to HABs. A portion of this revenue is profits. Retaining these profits would constitute a direct benefit, which would also be reflected in the value of businesses and commercial property.

  Very little specific and useful data regarding Lake Erie-related tourism and the effects of HABs is available and more thorough research is recommended. The approach used to assess tourism impacts in this report apportions aggregate estimates of tourism to identify tourism dollars that are at risk. This approach indicates that Ohio tourism dollars at risk range from $66 million to $305 million. Associated high-end lost profits are $20.79 million, and low-end lost profits are $165,000. In Michigan, a total of $24.78 million in tourism income is at risk. This is associated with high-end lost profits of $1.685 million and low-end estimates of $124,000. Similarly, Canadian tourism economic impacts total of $17.3

million with high and low profitability impacts ranging from $1.6 million to $59,000. Because of the lack of information that directly links tourism to HABs, these estimates are indicative of the sort of effects that could have occurred with the 2011 or 2014 HABs; however, the estimates are not specifically associated with the 2011 or 2014 events through quantification. Rather, they are preliminary indications of how HABs could affect income from tourism and the potential magnitude. In years and areas without significant blooms, lagged and halo effects may nevertheless result in tourists foregoing trips. Currently, there is no information available to quantify such effects and they are not distinguished from the high-level characterization summarized above.

- *Recreation:* Benefits lost to recreation activities included beach-going, fishing, and boating. Although no studies were available to directly link HABs to lost recreation, benefits were derived by transferring information from related literature. Quantified loss of benefits for beach-going are $14 million for 2011, and $11 million for 2014. For fishing, the benefits are estimated at $10 million for 2011, and $7 million for 2014. For boating, the benefits are $7 million for 2011, and $5 million for 2014. The overall benefits to recreation from the lack of a HAB event are $31 million for 2011, and $23 million for 2014. Specific studies directly quantifying how recreation activities respond to HABs are recommended.

- *Potential implications of HABs for water treatment:* The only information available identifying the costs for water treatment indicates that approximately $3 million per year is being incurred to deal with HABs (Ohio EPA, 2014). These expenditures will ensure a steady water supply, even during severe HAB events. In other words, repeats of the 2011 and 2014 events are not expected to cause service interruptions for these municipalities. For this reason, this study did not consider the welfare impacts of future interruption events in Toledo. Pelee Island's well water, however, is actually Lake Erie water, and there is no indication that expenditures have been undertaken to move well owners to municipal water. Consequently, an HAB event similar to 2014 would result in similar effects. The availability of Information to assess this effect is limited; however, these are estimated at $750,000.

- *Overall impacts:* Overall, under the scenarios developed here, the total impact of ecosystem service interruptions due to the 2011 HAB event is found to cost roughly $71 million ($16 million for property value, $20 million for tourism, $31 million for recreation, and $4 million for water treatment). For the 2014 HAB event, the estimate is roughly $65 million ($18 million for property value, $20 million for tourism, $23 million for recreation, and $4 million for water treatment

This study develops scenarios suggesting nearly $71 million in lost economic benefits from the 2011 HAB event, and an additional $65 million in lost benefits from the 2014 event.

As indicated previously and repeated throughout this report, these estimates are based on sound methods, but are preliminary due to the lack of data. The project team proposes the following points are investigated further:

- Develop an econometric model that links data on the presence and severity of HABs with sales data on the properties at risk to scientifically quantify the relationship between the presence and severity of HABs and property value losses. Such a study would replace the transfer and scenario-based evaluations conducted for this analysis with a parametrized evaluation of the property value effects of HABs.

- Identify if property effects of HABs, which differ in their impact every year, more closely resemble short-term disasters or events with effects spanning several years.

- Future work could also involve a more detailed study that accesses tax assessor data and more fully describes all the property values along the shore and in the nearshore areas where HABs are a risk.

- A related line of research could also incorporate homeowner preference data from surveys. Since shoreline and nearshore property owners are important stakeholders, a viable option for addressing the impacts of HABs on property values is to combine survey-based research approaches with formal property value models, as was done for contaminated sediment remediation in Waukegan Harbor (Braden et al, 2004).

- There are numerous parameters relating the presence and severity of HABs to changes in tourist activity that are not well understood and were specified as defined scenarios for this analysis. A key next step would be to develop scientifically-based evaluations of the following:

  - The proportion of late summer and early fall trips to counties that border western Lake Erie and are Lake Erie related.
  - Develop a scientific evaluation of the relationship between the presence of HABs and diverted tourist trips.
  - The relationship between the types of trips that are diverted because of the severity of HABs, where those trips are diverted to, and the amount of spending on those diverted trips.

- There is currently no study that links the presence and severity of HABs with changes in recreation demand. The analysis conducted for this report transfers results from other relationships to parameterize the effect that HABs have on beach use, fishing, and boating. However, a key next step would be to undertake a recreation demand study to quantify the effect that changes in the presence and severity of HABs has on recreational beach use, fishing, and boating demand. The study would also better quantify the baseline level of beach use, fishing, and boating trips to western Lake Erie.

- If current averting and treatment costs do not adequately protect against HAB interruptions to potable water supply or do not change individual, consumer behavior, further documentation on and research into losses of such events are highly warranted.

- Lastly, a key next step may also involve gathering behavior-specific and cost data on what residents of Pelee Island did to mitigate the 2014 HAB, how much they spent on their mitigation efforts, and identify whether they have made any capital investments or behavioral changes to avoid having to undertake those mitigation activities under future HAB events.

This study presents a HAB severity index, created for 2011 and 2014 events, that varies by week and county. This construct can easily be employed to evaluate future HABs events on Lake Erie.

In what follows, Section 2 presents a background of Lake Erie, discusses HABs and its various drivers, and concludes with a summary of recent HAB events. Section 3 presents a summary of economic methodology adopted in this report, and describes the novel approach used to quantify HAB severity by county/island and week. An analysis of value at risk and value lost due to ecosystem service interruptions for residential properties in shoreline and nearshore areas is presented in Section 4; Section 5 evaluates economic benefits of HAB reductions for three, interrelated sectors, namely tourism, business profitability, and commercial property values. The implications of HAB reductions on fishing, boating, and beach-going are evaluated in Section 6. This is followed by an evaluation of potential implications of HABs for water withdrawers in the western Lake Erie basin in Section 7. The report concludes by presenting a summary of proposed next steps in Section 8.

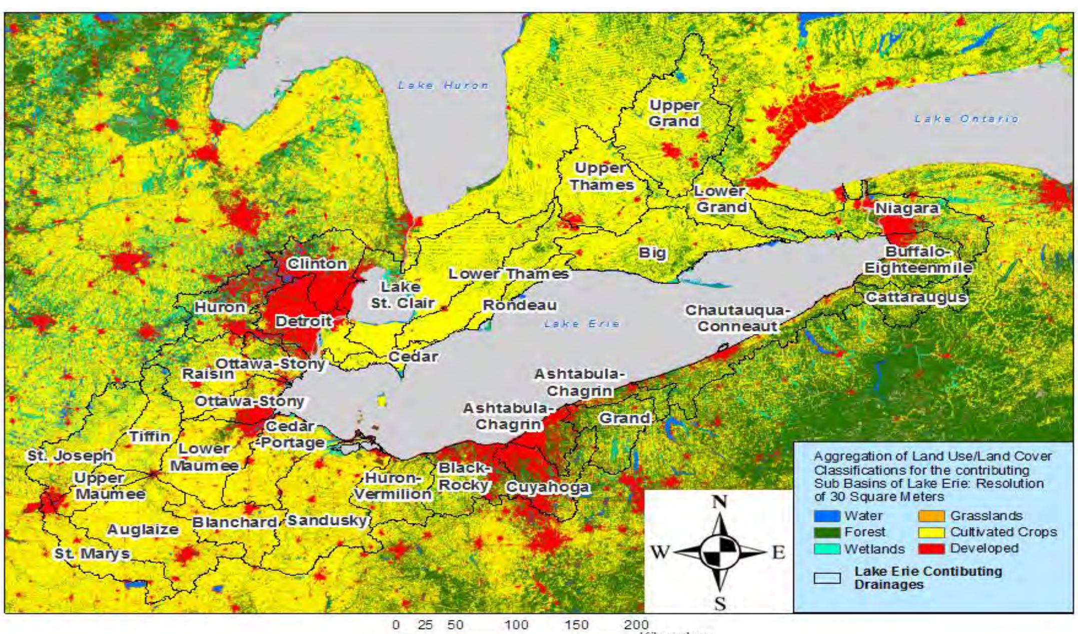
2.0 LAKE ERIE: OVERVIEW OF ITS ECOSYSTEM AND ALGAL BLOOMS

2.1 GENERAL BACKGROUND

Lake Erie plays a vital role in the overall health of the surrounding ecosystem. It is also integral to numerous sectors including tourism and commercial and recreational fishing, and is a municipal drinking water source. It has a surface area of 9,900 square miles and a mean depth of 62 feet, making it the shallowest of the Great Lakes. The lake is comprised of three separate basins—the east with an average depth of 79.3 feet, the west with an average depth of 24.1 feet, and one, centrally-located basin with an average depth of 60.1 feet (IJC LEEP 2014). The western basin's shallow depth makes it much more susceptible to temperature fluctuations, and is the origin of some of the most intense algae growth.

More than 90 percent of the discharge in Lake Erie flows in from the St. Clair River, which conveys water from lakes Huron, Michigan, and Superior. The second major contributor is the Maumee River watershed, which stretches all the way to Indiana. Lake Erie has a land basin of 22,700 square miles of watershed spanning five states and one Canadian province. This watershed sustains a human population of over 11.6 million people, making it the most densely populated of the Great Lakes (Lake Erie LaMP 2011). The majority of the population, including over three million Ohio residents, depends on Lake Erie for drinking water. Millions more rely on the water for agriculture use as over 63 percent of the watershed is currently cultivated (Figures 2-1 and 2-2), which is a large percentage compared to other lakes in the basin. Land use along its shoreline is dominated by residential uses (45 percent in the U.S. and 39 percent in Canada), agricultural uses (14 percent and 21 percent, respectively), and commercial uses (12 percent and 10 percent, respectively) (Environment Canada and USEPA 1995).

Figure 2-1: Land Use/Land Cover for the Lake Erie Basin



Note: The map is based on harmonized Canadian Fundamental Drainage Areas (FDA) and the U.S. Watershed Boundary Dataset (WBD). The Canadian Units are 4-digit Sub Basins and the U.S. Units are 8-digit Sub Basins.
Source: IJC LEEP Report, 2014.

Besides its use as a drinking water and farming source, Lake Erie plays a vital role in contributing to the economy in the area. In the Lake Erie region of Ohio alone, over $11 billion a year comes from money spent on tourism (Tourism Economics 2014). Commercial fishing of walleye, yellow perch, and other species in Lake Erie brings in more than $5 million a year (Ohio Department of Natural Resources 2012). There is also a considerable market for recreational fishing bringing in over $9.6 billion in revenue in 2010 through boating and other expenditures (Lucente et al 2012).

2.1.1 Harmful Algal Blooms (HABs) & Nuisance Algal Blooms (NABs)

Algae are one of the most diverse forms of life on earth, and they range in size from large, multicellular organisms, such as giant kelp on one end of the spectrum, to unicellular algae like diatoms on the other. NABs are generally non-toxic, and impact human health and economic activity through damaging aesthetics. They also impact ecosystems by creating zones of hypoxia. HABs, on the other hand, produce toxic substances that are capable of resulting in illnesses or death among humans and animals.

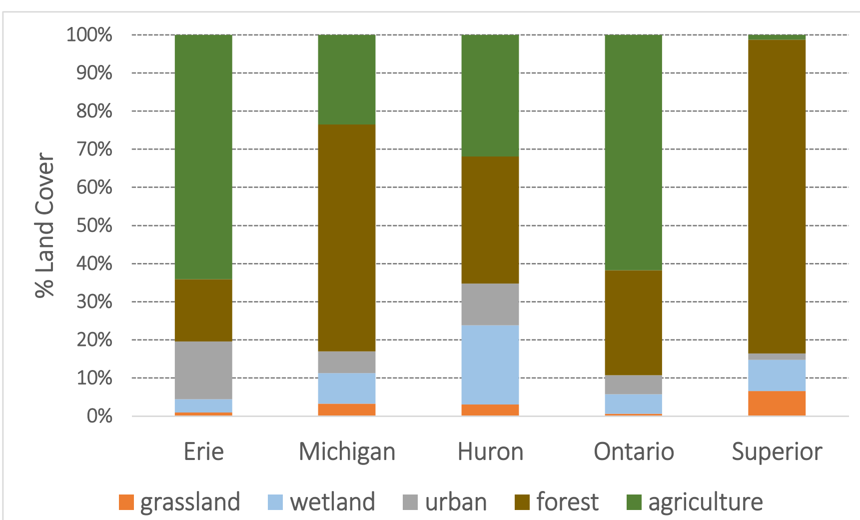
Overall, HABs and NABs result in two primary concerns within Lake Erie. The first is the formation of an enlarged, deep-water hypoxic zone in the central basin that has led to large fish kills and noxious odors. The second is the production of neurotoxins that are difficult to detect and costly to remove from drinking water sources. Hypoxic issues within Lake Erie likely predated human habitation, and records dating back to the mid-1900s show large areas (up to 4,000 square miles) becoming hypoxic during the summer months.

Catchment area land use in Lake Erie has a drastically higher agricultural focus than most other Great Lakes.

Recent algal bloom issues in Lake Erie closely mirror the original environmental issues that emerged in the 1970s. The need to address these issues precipitated the first U.S.-Canada Great Lakes Water Quality Agreement in 1972. In the original agreement, the primary pollutant of concern cited was total phosphorus (TP) load entering Lake Erie. In oligotrophic lakes such as Lake Erie, phosphorus availability is usually the resource that limits the productivity of the system.

Figure 2-2: Catchment Area Land Use in Lake Erie

shows a drastically higher agricultural focus than most other Great Lakes (Wang et al. 2015)



Wang, L., et al., A spatial classification and database for management, research, and policy making: The Great Lakes aquatic habitat framework, J. Great Lakes Res. (2015), http://dx.doi.org/10.1016/j.jglr.2015.03.017

Accordingly, that agreement sought to address the problem primarily by targeting contributions from facilities like the Detroit Wastewater Treatment Plant. Between 1970 and 1977, the Detroit Wastewater Treatment Plant made tremendous strides to address phosphorus loading. Since it began to take action, the facility reduced its phosphorus contribution to the Detroit River by over 90 percent. By targeting point sources simultaneously across the Lake Erie basin, after 1980, the TP load entering Lake Erie reduced significantly enough that the extent and frequency of algal blooms dropped markedly.

Unfortunately, there has been resurgence in the frequency of HABs and NABs even though phosphorus loads has remained consistently low. A recent paper by Smith et al. (2015) attributed this to bioavailable phosphorus for which they articulate the universe of drivers such as climate change, commodity prices, cropping system, crop nutrient efficiency, ethanol production, fertilizer placement/rates/source/timing, larger farms, manure, rental agreements, etc. In summary, TP is a measure that encompasses several chemical forms of phosphorus and, while the overall amount of phosphorus entering Lake Erie has remained relatively constant, the percentage of that total that is bioavailable phosphorus has been steadily increasing. This

Dead Fish in Western Lake Erie in 2011.

form of phosphorus, referred to as dissolved reactive phosphorus (DRP) or soluble reactive phosphorus is the form most easily used by photosynthetic organisms to carry out biological processes.

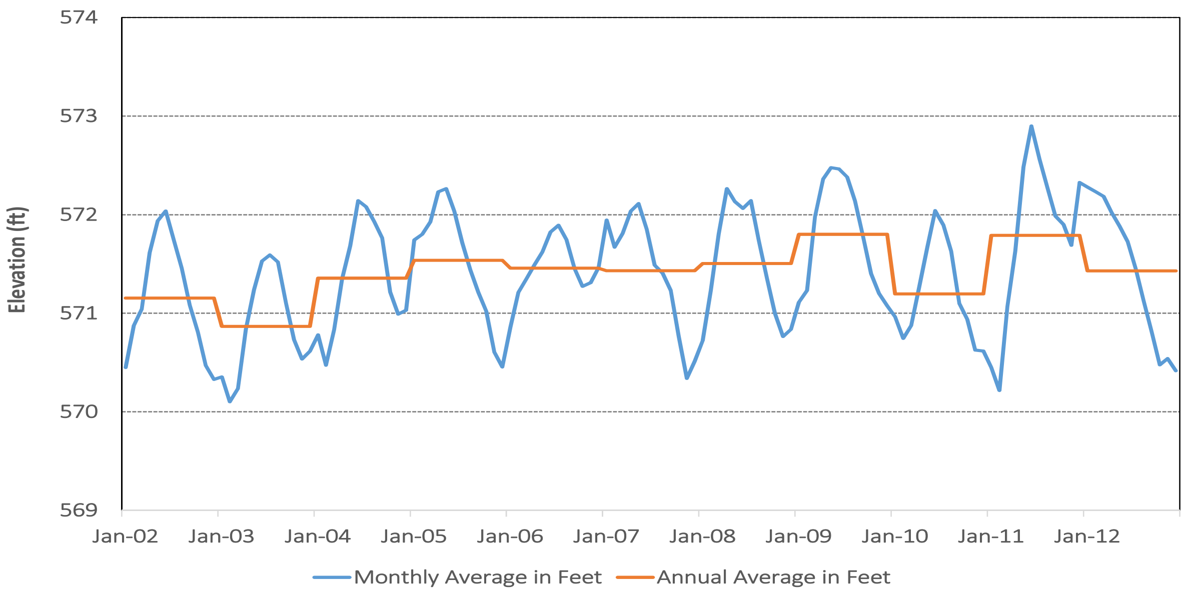
Predicting the exact size and location of algal blooms is very difficult.

There are two primary ways phosphorus loading occurs in Lake Erie, external loading and internal loading. External loading includes nonpoint sources, point sources, and atmospheric deposition of phosphorus. Internal loading is the result of the water column recycling phosphorus from organic sources (feces, decomposition of dead matter, etc.) and the release of phosphorus that is already stored in lake sediments. The key take away is that any action taken to reduce the overall load may take a few years to manifest as the phosphorus currently in the system cycles through the biological linkages. In other words, the loading trends combine to create a complex interaction, which makes predicting the exact size and extent of algal blooms very difficult.

2.1.2 Water Levels in Western Lake Erie

Water level data from Fairport Harbor gage (located roughly 30 miles northeast of Cleveland, Ohio), collected by National Oceanic and Atmospheric Administration (NOAA), illustrate the annual and seasonal fluctuations inherent to Lake Erie's hydrologic regime. Figure 2-3 shows the annual average lake level fluctuations over the past decade with generally increasing water levels from year to year.

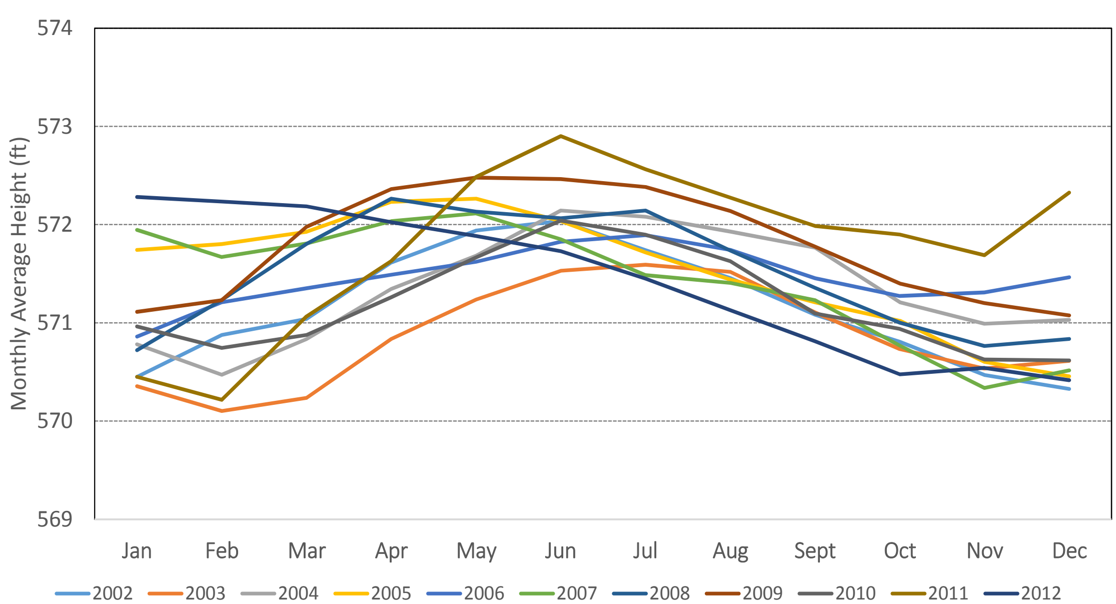
Figure 2-3: Lake Erie Water Level Variation Over the Last Decade



Source: (NOAA water level dashboard. (http://www.glerl.noaa.gov/data/dashboard/info/opLevels.html) Fairport, Ohio master gauge station)

Figure 2-4, on the other hand, illustrates the water level changes observed within the lake on a month to month basis. The chart illustrates a general trend of a low water level in the early spring months reaching a peak from March to July and then a falling lake level until November, with a yearly water level fluctuation of nearly two feet. The changes are largely consistent except for in 2012, when the water levels peaked in January and continued to decline throughout the year. Another exception is 2011 when, aided by intense spring rain, the water levels continued to increase from February through June.

Figure 2-4: Seasonal Variation of Water Levels Over the Years



Source: (NOAA, 2015. Fairport Ohio master gauge station)

2.1.3 HAB Drivers and History

The objective of this study is to investigate the economic benefits of reducing future HABs. Doing so requires developing a representation of future HAB-related ecological service reductions to inform scenario development. This section considers HAB drivers and recent history to inform this process.

HAB Drivers

Phosphorous loads are increasing in all watersheds of Lake Erie; loads from the Maumee River have increased by 218 percent since 1995 (Michalak et al. 2013). In addition, agricultural trends and practices indicate these trends are likely to continue. For example, corn is a particularly phosphate intensive crop (36 percent higher than soybeans) and between 2011 and 2012 alone, corn acreage increased by 15 percent in Ohio and 4 percent in Michigan (Michalak et al. 2013). Moreover, autumn applications and broadcast fertilizing remain common practices. These conditions are consistent with a potential for higher nutrient loading (Smith et al. 2015, Michalak et al. 2013). Considering phosphorous loading alone, this analysis anticipates that future blooms may be as large and common as in the recent past.

Given sufficient phosphorous levels, warm water temperatures and sunlight can combine to create conditions that are ideal for algal growth. Because these sunlight and water temperatures conditions typically occur during late summer and early fall, extensive HABs are most prevalent during these times (Koslow, Lillard, and Benka 2013). These factors are most typically prevalent in the western basin of Lake Erie due to the proximity of phosphorous sources and shallowness of this portion of the lake relative to the other basins. Accordingly, this evaluation indicates that future phosphorous blooms will be limited to Lake Erie's western basin and that they will occur in the late summer and early fall.

Although phosphorous is a requirement for HABs, this phosphorous must be suspended in the water column. Agricultural phosphorous becomes available to produce HABs in western Lake Erie via run-off and re-suspension. Run-off related blooms occur when heavy rains during the early spring and summer mobilize large phosphorous loads from farmlands. While these are suspended in the water column, they are available to fuel blooms. Re-suspension occurs when wind and wave action stirs up phosphorous that had previously settled, making it once more available for bloom formation. Unlike external loading, the weather events that lead to suspension tend to be rather unpredictable over long time periods.

Key meteorological factors that lead to HAB events, include rainfall, water temperatures, sunlight, water levels, wave, and wind actions.

Overall, these drivers indicate that intermittent HABs of varying sizes are anticipated in the future. These HABs are expected to occur in the western basin in the late summer and early fall. The location of the HABs is uncertain; depending upon where the HABs form, and wind and wave action they could be almost anywhere in the western basin.

The implication of this review is that future HABs will be much like the HABs of the recent past. As a result, in considering the reductions in ecological services and economic benefits of reducing future HABs, it is instructive to consider HABs of the recent past. The next several subsections provide a brief overview of HABs from 2011 through 2014.

2011 HAB

During 2011, several heavy flows from the Maumee occurred from March–May, followed by low water flows for the rest of the summer (Figure 2-4). The Detroit River usually provides dilution, but little occurred during that summer (Dolan et al. 2014). The International Joint Commission (2014) noted that the heavy spring rains of 2011 flushed a large amount of phosphorus into Western Lake Erie. This was soon followed by warm temperatures, creating a mass of algae that extended more than 1,930 mi^2 of Lake Erie's 9,900 square-mile surface area. Ohio Department of Agriculture et al. (2013) ranked spring discharge and loads for 38 years and found 2011 ranked first among those years in both discharge and dissolved reactive phosphorus (DRP), and third in TP. Richards (2013) and Stumpf et al. (2012) concluded:

- Spring discharge of the Maumee River from March–June 2011 was more than 5 cubic kilometers.
- Total phosphorus load from the Maumee River to Lake Erie during the spring was 2,240 metric tons.
- Spring DRP load from the Maumee River to Lake Erie was 419 metric tons.

Figure 2-5 shows the extent of the HAB in western Lake Erie during 2011. On the 1 to 10 scaled bloom severity index, the 2011 bloom was ranked 10 (Winslow 2015).

Figure 2-5: HAB in Western Lake Erie, 2011
Source: NOAA

2012 HAB

During 2012, with minimal rain throughout most of the year, the discharge, TP, and DRP from the Maumee River ranged from 15–20 percent of 2011's totals. The spring discharge and loads for 2012 ranked near the bottom of the 38-year rankings, and the HAB during 2012 was a fraction of the size of the 2011 HAB in Lake Erie (Ohio Department of Agriculture et al. 2013). Richards (2013) and Stumpf et al. (2012) concluded:

- Spring discharge of the Maumee River from March–June 2012 was about 1 cubic kilometer, 20 percent of the 2011 discharge.
- Total phosphorus load from the Maumee River to Lake Erie was nearly 381 metric tons during spring 2012, about 17 percent of the load for 2011.
- Spring DRP load from the Maumee River to Lake Erie during 2012 was about 60 metric tons, 15 percent of the load for 2011.

> ***Using NOAA's bloom severity index for Lake Erie blooms, the severity numbers for blooms between 2011 and 2014 are:***
>
> ***2011 = 10 2013 = 8.5***
>
> ***2012 = 2.5 2014 = 6.5***

Figure 2-6 shows the extent of the HAB in western Lake Erie during 2012. Monitors unexpectedly found a bloom in central Lake Erie. Using the NOAA bloom severity index for Lake Erie HABs, the 2012 bloom was ranked 2.5 (Winslow 2015).

Figure 2-6: HAB in Western Lake Erie, 2012
Source: NOAA

2013 HAB

During 2013, discharge from the Maumee River, total phosphorus load, and spring DRP load were higher than in 2012. Richards (2013) and Stumpf et al. (2012) concluded:

- Spring discharge of the Maumee River from March–June 2013 was 2.77 cubic kilometers.
- Total phosphorus load from the Maumee River to Lake Erie during the spring was 1,099 metric tons.
- Spring DRP load from the Maumee River to Lake Erie during 2013 was 238 metric tons (Richards and Baker 2013).

Figure 2-7 shows the extent of the HAB in western Lake Erie during 2013. Using the NOAA bloom severity index for Lake Erie HABs, the 2013 bloom was ranked 8.5 (Winslow 2015).

2014 HAB

As of June 2015, the 2014 spring discharge, total phosphorus load, and spring DRP load had not been published for the Maumee River. During early August 2014, wind and water currents pushed the HAB from Lake Erie's western basin to the area where Toledo, Ohio's Collins Park Water Treatment Plant takes in water from the lake affecting drinking water safety. The HAB also thickened around Pelee Island, Ontario, leading to beach and well closures as well as warnings against swimming, cooking, bathing, and eating fish from Lake Erie. Figure 2-8 shows the extent of the HAB in western Lake Erie during 2014. Using the NOAA bloom severity index for Lake Erie HABs, the 2014 bloom was ranked 6.5 (Winslow 2015).

Source: NOAA

Figure 2-7: HAB in Western Lake Erie, 2013

Source: National Aeronautics and Space Administration (NASA)

Figure 2-8: HAB in Western Lake Erie, 2014

3.0 METHODOLOGY TO CALCULATE ECONOMIC BENEFITS OF HAB REDUCTIONS

3.1 INTRODUCTION

Lake Erie is unique among the Great Lakes, with its shallow waters and southernmost location, resulting in the highest biological diversity and fish production of all the Great Lakes (Pearsall et al. 2012). The ecological services provided by Lake Erie include drinking water, biodiversity, recreation, wildlife habitat, the water cycle, primary productivity, nutrient cycling, sense of place, aesthetics, and climate regulation (Pearsall et al. 2012). HABs can interrupt these services on a broad scale for significant time periods and, consequently, the economic implications of HABs in western Lake Erie are far-reaching and complex.

The economic methods employed in this study are based on the concept of willingness to pay for improvements in ecological services. These improvements impact values which result in changes to behaviors, activities, and economic benefits.

In the first phase of HAB economics studies conducted by the IJC, Weicksel and Lupi (2013) studied the costs and certain economic benefits of reducing the 2011 HAB. Categories studied and cost/benefit estimates are depicted in Table 3-1. In addition to these, a discussion of critical information gaps and recommendations for additional research efforts (that have guided this study) were presented.

Table 3-1: Benefits and Costs Related to 2011 HAB Event (Weicksel and Lupi 2013)

BENEFIT OR COST CATEGORY	ESTIMATE OF ANNUAL BENEFIT OR COST	ADDITIONAL COMMENT
Costs to public water systems	$417,200	Recent costs are likely higher
Costs of reported illnesses	$2,128	
Costs of unreported illnesses	$16,720	
Property values	Not estimated	
Loss to beach recreation from advisories at Maumee Bay State Park	$1.3M	
Loss to beach recreation from advisories at other beaches	Not estimated	
Loss to beach recreation from excess algae at any impacted Great Lakes beach	Not estimated	Economic values measured in Weicksel (2012) but not yet available in monetary
Loss to beach recreation from clean-up of HABs	Not estimated	
Loss to recreational fishing	$2.4M	Impact from HABs may only be apparent over time
Loss to recreational boating (non-fishing related)	Not estimated	
Loss to commercial fishing	Not estimated	Impact from HABs may only be apparent over time
Loss to tourism industry	Not estimated	Impact from HABs may only be apparent over time
Loss to charter boat industry	Not estimated	
Benefits outside of Ohio	Not estimated	
Dissolved Reactive Phosphorus (DRP) reduction from all other sources	Not estimated	
Cost of DRP reduction from Agriculture	Median value of estimated ranges approximately $30M	Based on assumed mix of best management practices adoption
Cost of DRP reduction from areas outside of Ohio	Not estimated	

This effort extends the Phase 1 study by further evaluating HAB effects to regional economic welfare including effects on recreation, water withdrawals, tourism, and property values. Results of the Phase I effort indicate that western basin HABs can affect interrelated economic systems over a broad, geographic area and that little information has been collected to specifically support economic benefit studies. This study has benefited from the previous work conceptually and methodologically, however, the problem of information limitations persists. For example, certain potentially observable information, such as timing and severity of HABs at a micro-level (beach, marina, neighborhood), as well as short run responses of people (recreators, tourists) and markets (rental, hotel, housing, restaurants) to the HABs are not available.

An additional challenge is that certain responses of people and markets may not result directly from any specific HAB incident. Rather, these responses (termed lagged and halo effects in the Phase 1 report) occur in different places and time periods than HABs and result from more complex cognitive and economic processes than the comparatively easy to measure (with appropriate data) economic effects that arise from ecological service reductions. As a result of these two factors, it is not currently feasible to quantify the economic effects of HABs in the scientific sense of identifying statistically significant parameters within rigorous econometric models. Not having that capability, this effort relies on available secondary data and studies. For certain effects, this information is incorporated into an evaluation of "value at risk" that employs scenarios and sensitivity analyses to characterize ecological service interruptions and their immediate economic effects. Less immediate (i.e., lagged and halo) effects are discussed and quantified in the context of these effects.

3.2 ECOLOGICAL SERVICES AND ECONOMIC BENEFITS

This study adopts a forward-looking perspective, which is intended to identify the economic benefits of reductions in *future* HABs. Thus, although the scenarios considered are based on past events (i.e., ex post), these events are considered as they would occur in the future. This ex ante (forward looking) viewpoint applies because of its policy relevance. A result of applying this policy-relevant approach is that the degree to which previous mitigating actions have been taken affects whether or not some impacts are included in the evaluation.

For example, HABs resulted in economic damages due to interruption of water services in Toledo, Ohio, and on Pelee Island, Ontario. In Toledo, the municipal water system was affected and expenditures for preventive measures were made so that water services would not be interrupted in the future. On Pelee Island, well water was affected, but there is no indication steps have been taken to avoid interruption of water services in the future. Consequently, when evaluating the *benefits of future HAB reductions*:

- Past damages incurred on Pelee Island are measured.
- Past damages incurred in Toledo are *not* measured, although ongoing HAB-related expenditures for Toledo's water system are counted.

The policy relevant (forward looking) model used in this study:

- considers future events,
- considers mitigating actions, and
- does not predict HABs

The economic methods employed in this study are based on willingness to pay for ecological services. Reductions in these services impact values. That results in changes to behaviors and activities, ultimately affecting economic benefits. This process is depicted in Figure 3-1.

Figure 3-1: Economic Relationships

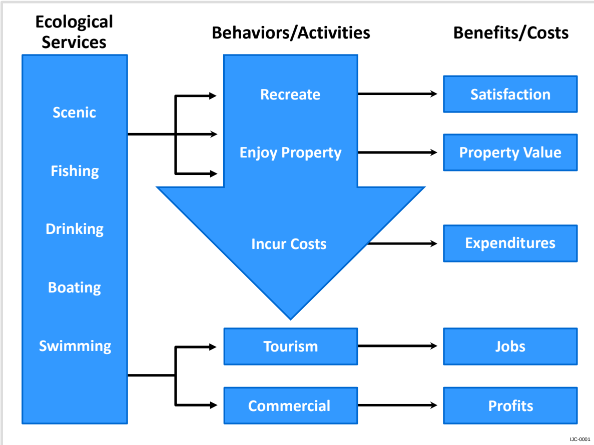


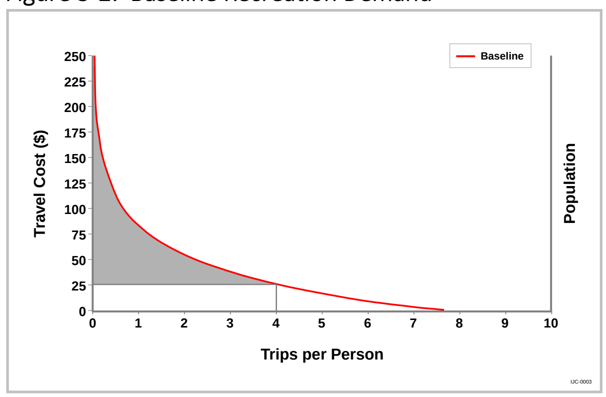
Figure 3-1 depicts a number of important features of this analysis. The first relates to the ecological services which are interrupted. There are a number of these, and they are potentially inter-related. Changes in these services lead to changes in behaviors and activities that are also interrelated. Thus, changes in fishing quality could conceptually affect local fishing trips, tourist trips, commercial activity and profits, commercial property value, and residential property value. It is important and challenging to capture changes in benefits without "double counting" (counting the same benefit in different categories) and this study endeavors to do so.

3.2.1 *Economic Values and Behavior*

The conceptual foundations of this study rely on individual preferences. People express preferences through the choices and trade-offs that they make, given constraints, such as income or available time. Economic value is measured by the maximum that someone is willing to give up in other goods and services to obtain a different good, service, or state of the world. This is measured for an individual by consumer surplus, which is, conceptually, the amount that he or she is *willing* to pay, beyond what is actually paid; if someone is willing to pay $5 for an item, but the market price is $3, then the consumer surplus for that item is $2.

A particularly important consideration relates to distinguishing between the dollar values that are associated with the behaviors and activities of the second column of Figure 3-1 and the economic benefits/costs of the final column. Whereas the economic benefits listed in the third column can be thought of as what an individual, or individuals aggregated up to the societal level, would be willing to pay for a different state of the world. The economic impacts listed in the second column refer to changes in expenditures. The following figures depict related concepts. Figure 3-2 depicts a recreation site's demand curve. In this figure, the red curve represents both the total value individual recreators receive and the number of trips the recreators would take at any particular cost.

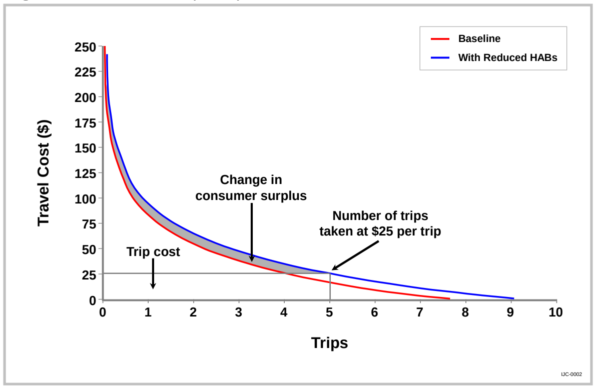
Figure 3-2: Baseline Recreation Demand



As depicted, a recreator incurs costs of $25 per trip and takes four trips per year for total expenditures of $100 per year. The monetized measure of value is the area below the demand (or willingness to pay) curve but above the $25 cost (the grey shaded area).

Figure 3-3 depicts a change in value, behavior, and expenditures that would occur with improved ecological services. In this figure, the demand curve has shifted outward; because the quality of ecological services has improved, the recreator is willing to pay more for any given number of trips. The economic value of the improvement is the change in the area underneath the demand curve. When economists speak of the economic benefits associated with a change in recreation site quality, this is the quantity to which they refer.

Figure 3-3: Quality Improved Recreation Demand



As can be seen in this figure, there is a higher value for trips 1 through 4, and the recreator experiences a welfare improvement without any corresponding change in behavior. However, with the improvement in site quality, there is also a change in behavior; the recreator takes an additional trip. This additional trip is taken because ecological service quality has improved. The value of taking this trip is now greater than its cost. Additional expenditures of $25 are incurred and some additional economic benefits are captured.

Regarding the $25 in additional expenditures, in conventional environmental economic analyses this quantity is only considered in that it is subtracted away from the change in value. Thus, although the $25 may have been spent at for example a gas station, beach, or bait shop, this expenditure is not valued. There are a number of reasons for this. For one, oftentimes resource evaluations consider a particular population. For example, if the study considers benefits to recreators, the $25 can be forgotten because recreators do not receive this money, rather they spend it. Although it may seem appropriate to broaden the population being considered, this brings in an additional complication in that it requires a somewhat arbitrary restriction to the population that can receive benefits. If this is not done the benefits are diluted into transfers. Consider including benefits to local merchants. In this case, note that taking the fifth trip implies some other activity is *not* undertaken. The implication is the $25 gained by the gas station, bait shop, or beach store is likely lost to some other retailer, such as a bowling alley owner. Moreover, even if the population were restricted to gas station, beach, and bait shop owners, this $25 is still not an economic benefit. Rather, it is a change in revenue. Understanding the change in benefits that accompanies this change in revenue requires further evaluations. These include both quantifying how these expenditures ripple through a local economy leading to revenue changes in other sectors and identifying the economic benefit that accompanies these revenue changes.

The policy focused (forward looking) model used in this study:

- ***considers future events,***
- ***considers mitigating actions, and***
- ***does not predict HABs.***

3.2.2 Economic Activity and Benefits

Although environmental economics studies often do not consider these effects, in some cases doing so is appropriate. Considering the current case, HABs have the potential for dramatic effects on local populations that rely extensively on the ecological services that Lake Erie provides. For example, tourists come to Lake Erie from all over the U.S. to enjoy the fishing. As tourists forego these trips, many other destinations would experience marginal visitation improvements, however, communities near Lake Erie may experience pronounced losses both in economic activity and economic benefits.

This study captures this effect using a technique called input-output analysis. Input-output analysis is a mathematical-economic technique that assesses the effects of economic impacts in a particular economic system (e.g., town, county, state, region, or national level). Input-output analysis measures *direct effects* (such as the $25 described earlier) as well as *indirect effects*, which are changes in inter-industry transactions as supplying industries respond to increased demands from the directly affected industries, and *induced effects,* which reflect changes in local spending that result from income changes in the directly and indirectly affected industry sectors. More information about this is provided in the section that evaluates tourism effects.

These revenue and job changes can have benefits. Increases in revenue often increase profits and jobs can improve welfare. As described elsewhere in this section, identifying these changes requires defining a population for which impacts are measured. The following sections describe how these economic considerations are combined with ecological effects and economic concepts to identify scenarios and populations that are studied.

3.3 HAB SCENARIOS STUDIED IN THIS REPORT

Based on the review of the factors that underlie HABs (Section 2), it appears likely that HABs of varying levels of severity will continue to manifest in Lake Erie. Similar to 2011 and 2014 and the years between, the magnitude and location of these HABs will be relatively unpredictable but will continue to have the potential for relatively large and far-reaching economic effects. Consequently, when considering the *immediate* (i.e. within-year) effects, evaluation of past HABs is adopted as the approach for identifying the economic effects that would accompany reductions in future HABs.

Lagged benefits are defined as benefits that occur outside the year of the evaluated HABs, but are related to them. Because lagged effects would be associated with the most impactful HABs, the most damaging recent HABs (2011 and 2014) are evaluated.

3.3.1 Quantifying Ecological Service Reductions

Conducting this approach requires specifying service reductions for 2011 and 2014. However, although information about closures of beaches and water treatment facilities is available, there are no data related to less dramatic reductions in tourism, recreation, and property value/enjoyment. Moreover, quantitative information that is useful for inferring these impacts does not exist either. While pictures of HABs that depict ecological service reductions (contaminated shorelines, clogged marinas) are readily available, no reliable quantitative or written information that indicates the date, location, and severity of HABs could be identified.

As a part of this study, Project Team converted satellite images from NOAA to numeric representations of HAB severity by week and county/island for the HABs of 2011 and 2014.

Given this limitation, the team developed this information by converting satellite images and other available information, such as news reports, into a numeric representation of HAB severity by date and location for 2011 and 2014. These images and other data help establish where and when HABs potentially affect the uses of Lake Erie (NOAA Great Lakes Environmental Research Laboratory [GLERL], 2015). Although many overhead images of Lake Erie's algal blooms are publicly available, most are not precisely dated. This study relied on dated satellite images from NOAA.

For several years, NOAA posted Medium-Spectral Resolution Imaging Spectrometer (MERIS) imagery of Lake Erie until the MERIS satellite stopped communicating during 2012. Since then, NOAA has posted images of Lake Erie HABs from the Moderate Resolution Imaging Spectro-Radiometer (MODIS) on the AQUA satellite. Both MERIS and MODIS imagery are dated weekly or oftener.

HAB severity ratings used in this study are as follows:

- 0 means that the HAB was absent or not visible in that area
- 0.25 means that the HAB was visible within or affected a small part of the area
- 0.50 means that the HAB was visible within or affected about half of the area

- 0.75 means that the HAB was visible within or affected most of the area
- 1 means that the HAB was severe and visible or affected the entire area

The finest degree of temporal and spatial specificity deemed possible is weekly and at county (mainland) shorelines and three island groupings, as described in the following sections.

3.3.2 The 2011 HAB

During 2011, Lake Erie's HAB formed in the western basin by mid-July, at that time covering about 600 km^2. The bloom was composed almost entirely of *Microcystis*. On July 16, satellite imagery showed the bloom hugging the shoreline of Essex County, Ontario and most of the shoreline of Wayne County, Michigan. The bloom hugged the shorelines of Monroe County, Michigan, and the western half of Lucas County, Ohio, as well as spreading miles offshore into Lake Erie. During late July, the Microcystis toxin level measured more than 1000 ug/l at Toledo Light #2 in Lake Erie, 14.5 nautical miles from the mouth of the Maumee River, Ohio (Michalak et al. 2013; NOAA GLERL 2015). The month of July 2011 is represented in Table 3-2.

Table 3-2: Severity Rating for HABs in the Western Basin of Lake Erie, July 2011

County or Island	Weeks of July 2011			
	1	2	3	4
Essex mainland	0	0	0.25	0
Pelee Island	0	0	0	0
Wayne (southern tip)	0	0	0	0
Monroe	0	0	0.50	0.50
Lucas	0	0	0.50	0.25
Ottawa mainland	0	0	0	0
Bass Islands	0	0	0	0
Sandusky	0	0	0.50	0.25
Erie mainland	0	0	0	0
Kelleys Island, Erie County	0	0	0	0

Sources: NOAA GLERL (2015); Shuchman et al. (2015); International Joint Commission (2014); Michalak et al. (2013)

By early August, the bloom remained in those waters and spread to the:

- entire coastline of Lucas County, Ohio
- Pelee Island, Ontario
- Ottawa County, Ohio, including the Bass Islands
- Sandusky County, Ohio (by this time and in following months *Planktothrix* spp. dominated the bloom in Sandusky waters)

During mid-August to August 23, the bloom was present in the waters of the entire western basin of Lake Erie (NOAA GLERL 2015). The month of August is represented in Table 3-3.

Table 3-3: Severity Rating for HABs in the Western Basin of Lake Erie, August 2011

County or Island	Weeks of August 2011			
	1	2	3	4
Essex mainland	0	0.25	0.50	050
Pelee Island	0	0.25	0.25	0.50
Wayne (southern tip)	0	0.25	0.25	0.50
Monroe	0.25	0.50	0.50	0.75
Lucas	0.50	0.75	1	1
Ottawa mainland	0	0.25	0.50	0.75
Bass Islands	0	0	0.25	0.50
Sandusky	0.25	0.50	0.50	0.50
Erie mainland	0	0	0	0.25
Kelleys Island, Erie County	0	0	0.25	0.50

Sources: NOAA GLERL (2015); Shuchman et al. (2015); International Joint Commission (2014); Michalak et al. (2013)

By September 3, satellite imagery shows the bloom moving away from the Essex County, Ontario, shoreline. The bloom moved away from Ohio county shorelines, remained on Michigan shorelines, and returned to Essex County by September 14. Satellite imagery from September 16 shows the *Microcystis* bloom on the shoreline of the entire western basin, except for a small portion of Essex County, Ontario. NOAA's

"Experimental Lake Erie Harmful Algal Bloom Bulletin 2011-015" stated that the concentrations of the *Microcystis* bloom were greatly reduced by wind stress that "caused mixing and much of the biomass is likely to be subsurface (> 1 meter)" (NOAA 2011). On September 27, satellite imagery still showed the *Microcystis* bloom on the shoreline of the western basin, except for portions of Essex County, Ontario (NOAA GLERL 2015). September 2011 is represented in Table 3-4.

Table 3-4: Severity Rating for HABs in the Western Basin of Lake Erie, September 2011

County or Island	Weeks of September 2011			
	1	2	3	4
Essex mainland	0	0.75	0.50	0.50
Pelee Island	0.75	1	0.75	0.75
Wayne (southern tip)	0.25	0.50	.075	0.25
Monroe	1	0.50	0.75	0.50
Lucas	1	0.50	.075	0.50
Ottawa mainland	0.50	0.25	0.50	0.50
Bass Islands	1	1	0.75	0.25
Sandusky	1	0.50	0.75	0.50
Erie mainland	0.25	0.25	0.50	0.75
Kelleys Island, Erie County	0.25	0.50	0.75	1

Sources: NOAA GLERL (2015); Shuchman et al. (2015); International Joint Commission (2014); Michalak et al. (2013)

By October 11, satellite imagery showed the bloom near the shoreline of the entire western basin. On satellite imagery from October 17, most shorelines of the western basin showed no *Microcystis* bloom. By the end of October, the bloom had dissipated from Lake Erie (NOAA GLERL 2015). October 2011 is represented in Table 3-5.

Table 3-5: Severity Rating for HABs in the Western Basin of Lake Erie, October 2011

County or Island	Weeks of October 2011			
	1	2	3	4
Essex mainland	0.50	0.75	0.25	0
Pelee Island	0.50	0.50	0.25	0
Wayne (southern tip)	0	0	0	0
Monroe	0.25	0.75	0	0
Lucas	0	0.50	0	0
Ottawa mainland	0.25	0.50	0	0
Bass Islands	0.25	1	0.25	0
Sandusky	0.25	0.50	0.25	0
Erie mainland	0.75	1	0	0
Kelleys Island, Erie County	0.75	1	0.25	0

Sources: NOAA GLERL (2015); Shuchman et al. (2015); International Joint Commission (2014); Michalak et al. (2013)

3.3.3 *The 2014 HAB*

During 2014, Lake Erie's HAB formed by July 14 near the Maumee River. By the third week of July, Ohio EPA observed 7.1 ppb of Microcystins at Maumee Bay State Park and issued a Recreational Public Health Advisory. By the end of July, the bloom spread northward up the coast of Monroe County, Michigan, eastward along the Ottawa County, Ohio, shoreline, and miles into Lake Erie (NOAA GLERL 2015; Shuchman et al. 2015). July 2014 is represented as in Table 3-6. Tables 3-6 through 3-9 are based in part on "Algal Toxin Results from Lake Erie, Ohio State Park Beaches, and Public Water Supplies (2011–Present)" from Ohio EPA (2015), as released to the public on May 29, 2015.

Table 3-6: Severity Rating for HABs in the Western Basin of Lake Erie, July 2014

County or Island	Weeks of July 2014			
	1	2	3	4
Essex mainland	0	0	0	0
Pelee Island	0	0	0	0
Wayne (southern tip)	0	0	0	0
Monroe	0	0	0.50	0.75
Lucas	0.25	0.25	0.75	1
Ottawa mainland	0	0	0.25	0.5
Bass Islands	0	0	0	0
Sandusky	0.25	0.50	0.50	0.75
Erie mainland	0	0	0	0
Kelleys Island, Erie County	0	0	0	0.25

Sources: NOAA GLERL (2015); Shuchman et al. (2015); CTV Windsor (2014); Dierkes (2014); Dolan (2014); Kisonas (2014); Sonich-Mullin (2014); *Toledo Blade* (2014)

During early August, the HAB intensified and spread northward to include Monroe County. The HAB also spread to most of Ottawa County, Ohio's coastline and moved toward Pelee Island, Ontario. Wind and water currents pushed the

HAB from Lake Erie's western basin to the area where Toledo, Ohio's water treatment plant takes in water from the lake. Winds during August mixed some of the HAB into the lake water so that less of the HAB was visible on satellite imagery. By the end of August, the HAB extended well past the islands in Lake Erie and along most of the western basin's southern coastline (NOAA GLERL 2015; Dierkes 2014; Dolan 2014; Sonich-Mullin 2014). August 2014 is represented in Table 3-7.

Table 3-7: Severity Rating for HABs in the Western Basin of Lake Erie, August 2014

County or Island	Weeks of August 2014			
	1	2	3	4
Essex mainland	0	0	0	0
Pelee Island	0	0.25	0.25	1
Wayne (southern tip)	0	0	0	0
Monroe	1	0.50	0.50	0.50
Lucas	1	1	1	1
Ottawa mainland	0.50	0.50	0.50	0.50
Bass Islands	0	0.25	0.50	1
Sandusky	0.75	0.50	0.25	0.50
Erie mainland	0.25	0.25	0.25	0.25
Kelleys Island, Erie County	0.25	0.25	0.50	0.50

Sources: NOAA GLERL (2015); Shuchman et al. (2015); CTV Windsor (2014); Dierkes (2014); Dolan (2014); Kisonas (2014); Sonich-Mullin (2014); *Toledo Blade* (2014)

Winds during September kept the most intense area of the HAB in Maumee Bay, but also kept the bloom around the Lake Erie islands. For 15 days during late August into September, residents of Pelee Island, Ontario, were warned not to use well water because elevated levels of microsystin were detected in the water. Winds also moved the HAB so that it collected on the shoreline of Ontario in the central basin of Lake Erie. Calm winds later in the month promoted the formation of scum on the HABs around the Lake Erie islands and in Maumee Bay (NOAA GLERL 2015; CTV Windsor 2014; *Toledo Blade* 2014). September is represented in Table 3-8.

Table 3-8: Severity Rating for HABs in the Western Basin of Lake Erie, September 2014

County or Island	Weeks of September 2014			
	1	2	3	4
Essex mainland	0	0	0.25	0.50
Pelee Island	1	1	0.25	0.50
Wayne (southern tip)	0.25	0	0	0
Monroe	0.75	0.50	0.50	0.75
Lucas	0.75	0.75	0.50	0.75
Ottawa mainland	0.50	0.50	0.50	0.25
Bass Islands	1	1	0.50	0.75
Sandusky	0.50	0.50	0.75	0.50
Erie mainland	0.25	0.25	0.50	0.25
Kelleys Island, Erie County	0.50	0.50	0.50	0.25

Sources: NOAA GLERL (2015); Shuchman et al. (2015); CTV Windsor (2014); Dierkes (2014); Dolan (2014); Kisonas (2014); Sonich-Mullin (2014); *Toledo Blade* (2014)

During early October, winds pushed a substantial portion of the HAB to the Ontario shoreline in the western basin of Lake Erie, and a portion of the bloom intensified in the central basin of Ontario waters. The HAB grew near Maumee Bay and the waters of Monroe County, Michigan. The HAB weakened throughout the western basin and dissipated from the central basin by mid-October. A small bloom patch remained offshore of Monroe County, Michigan, on October 22, but by that time the water temperature dropped below 59°F, when *Microcystis* stops growing. By the end of October, only Sandusky Bay showed a HAB on satellite imagery (NOAA GLERL 2015). October is represented in Table 3-9.

Table 3-9: Severity Rating for HABs in the Western Basin of Lake Erie, October 2014

County or Island	Weeks of October 2014			
	1	2	3	4
Essex mainland	0.50	0	0	0
Pelee Island	0.25	0	0	0
Wayne (southern tip)	0	0	0	0
Monroe	0.50	0.25	0	0
Lucas	0.50	0.50	0.25	0
Ottawa mainland	0.25	0	0	0
Bass Islands	0.25	0.25	0	0
Sandusky	0.25	0.25	0.50	0.25
Erie mainland	0.25	0.25	0	0
Kelleys Island, Erie County	0.25	0	0	0

Sources: NOAA GLERL (2015); Shuchman et al. (2015); CTV Windsor (2014); Dierkes (2014); Dolan (2014); Kisonas (2014); Sonich-Mullin (2014); *Toledo Blade* (2014)

This information is incorporated into the evaluation of effects to recreation, water withdrawals, tourism, and property values as described within each section.

4.0 IMPACTS OF HABS ON RESIDENTIAL PROPERTY VALUES

4.1 RESIDENTIAL PROPERTY VALUES

The Phase I effort noted that effects to residential property values are a potentially important area for study. However, information related to the value of properties that could be impacted, as well as the nature and magnitude of this effect from HABs was not readily available. Considering the former, the initial effort demonstrated the expected result - that properties closer to the Lake Erie shore are expected to generally have a higher value. In particular, a 2001 study by Seiler et al. used a hedonic pricing model of homes near Cleveland, Ohio, and estimated that all else equal, houses that have a view of Lake Erie are an average of 56 percent more valuable than houses that do not have a view of Lake Erie.

With respect to the nature of HAB effects on property values, HABs can produce strong odors and can make typically clear and clean-looking water appear cloudy, murky, and polluted. In this way, the presence of HABs can adversely affect the aesthetics of nearby properties (ODH, OPEA and ODNR 2012). HAB effects have not been explicitly studied; however, several studies have looked at the relationship between housing values and Lake Erie water quality. These studies typically employ hedonic analysis. For water quality, this econometric approach observes the values of homes purchased near water bodies of varying environmental qualities, and allows statistically identifying the value that markets assign to environmental characteristics.
Ara et al. (2006) use a hedonic pricing analysis of the value of houses near Lake Erie and found that changes in water quality in Lake Erie have significant impacts on the value of nearby houses. The model predicts that an increase in water quality at Lake Erie beaches comparable to a one-meter increase in secchi disk depth could increase housing values in that beach's county from $221 to $2,379 (1996 USD) per house, depending on the beach nearest to the home in question. This model also estimates that homes in the area of beaches experiencing unsafe levels of fecal coliform counts would benefit from a reduction in fecal coliform to safe counts (i.e., 200 counts per 100 mL) in the amount of $88 to $2,692 (1996 USD) per house.

> ***Seiler et al. (2001) used a hedonic pricing model of homes near Cleveland, Ohio, and estimated that all else equal, houses that have a view of Lake Erie are an average of 56 percent more valuable than houses that do not have a view of Lake Erie.***
>
> ***HABs can produce strong odors and can make typically clear and clean-looking water appear cloudy, murky, and polluted, adversely impacting the aesthetics of nearby properties.***

This review indicates several important outcomes:

1. Other things being equal, properties that are closer to the shoreline of Lake Erie are more valuable than properties that are further from the shoreline.
2. The 2011 and 2014 HABs clearly had the potential to diminish ecological service-related qualities of shoreline and near-shore properties.
3. Near-shore properties experience a proportionately greater reduction in property value from lower water quality than to properties that are farther away.

With these considerations in mind, an attempt at valuing impacts was undertaken as part of this effort. This effort can be roughly described as attempting to identify the market value of properties that are most likely to be affected by HABs ("value at risk") and the potential effect of HABs on the value of those properties. Areas studied are within the counties depicted in Figure 4-1.

Figure 4-1: Potential for Property Value Impacts

4.2 VALUE AT RISK

An important first step in characterizing the potential for property value impacts is developing an understanding of the value of the housing stock that is likely to be affected by HABs. For Canada, there are no suitable data sources available. For the U.S. there are a number of potential data sources for identifying residential property values. Multiple listing service (MLS) data are the primary data typically used for hedonic analysis. This data consists of sale prices and property characteristics for homes sold in a given area and over a certain time period. Although these data would be useful for an econometric evaluation of effects of environmental dis-amenities on home values, it was determined that it is not useful for identifying baseline residential property values that are at risk. The reason for this is that the MLS data typically only contain sales and are therefore too sparse for identifying the totality of properties whose value could be affected.

The Phase I effort noted the potential for using assessor data to identify the amount of home values exposed to the effects of HABs. Because these assessed values do not represent market values, such data are rarely if ever used in published hedonic analysis. For identifying value at risk, this is not a great detriment. However, our investigation indicated that assessors' data are available at the county or city level in Ohio and Michigan. Users of the data need a parcel ID or an address to access the data. (Ontario properties use a roll number.) As a result, without an address-level breakdown or unique identifier, the data cannot be used to identify property values by their location. This makes it costly to account for the proximity-related effects described in factors 1 and 3 above.

Value at risk was estimated for shoreline properties as well as for nearshore properties (the latter are defined as those within one-half mile of shore).

The team also evaluated the viability of data from the U.S. Census Bureau (2015). Census Bureau data on value are available from report B25075. This report arises from Housing Question 19 in the American Community Survey which asks "About how much do you think this house and lot, apartment, or mobile home (and lot, if owned) would sell for if it were for sale?" This question was asked at housing units that were vacant and occupied, including those that are owned, being bought, and for sale. Value is the respondent's estimate of how much the property would sell for if it were for sale. If the house or mobile home was owned or being bought, but the land on which it sits was not, the respondent was asked to estimate the combined value of the house or mobile home and the land. For units that were for sale, value was the price being asked for the property.

The U.S. Census Bureau used data from the 2009–2013 American Community Survey five-year estimates to compile the most recent report B25075. This report is available at various census groupings and consists of the estimated number of properties within 24 ranges of property values (Table 4-1).

Table 4-1: Ranges of Property Values Used in the Analysis, U.S. Census Report B25075

Lucas County, Ohio: Census Tract 97, Block Group 3		
Range of Values	Number of Properties	Margin of Error
Less than $10,000	0	+/-11
$10,000 to $14,999	7	+/-12
$15,000 to $19,999	0	+/-11
$20,000 to $24,999	0	+/-11
$25,000 to $29,999	0	+/-11
$30,000 to $34,999	0	+/-11
$35,000 to $39,999	0	+/-11
$40,000 to $49,999	17	+/-20
$50,000 to $59,999	9	+/-14
$60,000 to $69,999	32	+/-30
$70,000 to $79,999	39	+/-28
$80,000 to $89,999	32	+/-29
$90,000 to $99,999	53	+/-55
$100,000 to $124,999	11	+/-16
$125,000 to $149,999	37	+/-28
$150,000 to $174,999	0	+/-11
$175,000 to $199,999	0	+/-11
$200,000 to $249,999	0	+/-11
$250,000 to $299,999	25	+/-23
$300,000 to $399,999	10	+/-15
$400,000 to $499,999	0	+/-11
$500,000 to $749,999	7	+/-11
$750,000 to $999,999	0	+/-11
$1,000,000 or more	0	+/-11

This information is available at the census tract and block group level. The U.S. Census Bureau (2012, 1994) publishes its rules for developing various groupings. These rules were evaluated to identify the value of using census data to identify property values. Although property value information is not available at the block level, the process for developing blocks was considered. Census tracts are intended to provide a stable set of geographic units for the presentation of statistical data. Census tracts usually cover a contiguous area; they have an optimum population size of 4,000 people and can range between 1,200 and 8,000 people. Their size can vary according to population density. Census tract boundaries are delineated with the intention of being maintained over a long time so that statistical comparisons can be made from census to census. Census tracts occasionally are split due to population growth or merged as a result of substantial population decline. Census tract boundaries generally follow visible and identifiable features. State and county boundaries always are census tract boundaries (U.S. Census Bureau 2012).

Block groups are statistical divisions of census tracts, are generally defined to contain between 600 and 3,000 people, and are used to present data and control block numbering. A block group consists of clusters of blocks within the same census tract. A block group usually covers a contiguous area. Each census tract contains at least one block group, and block groups are uniquely numbered within the census tract. Within the standard census geographic hierarchy, block groups never cross state, county, or census tract boundaries but can cross the boundaries of any other geographic entity. Most block groups were delineated by local participants in the Census Bureau's Participant Statistical Areas Program (U.S. Census Bureau 2012).

Census blocks are the smallest geographic area for which the Bureau of the Census collects and tabulates decennial census data. The minimum size of a census block was 30,000 square feet (0.69 acre) for polygons bounded entirely by roads, or 40,000 square feet (0.92 acres) for other polygons. Although there is no maximum size for a block, it must be the same size or smaller than the block group it is contained in, which must be the same or smaller than the corresponding tract. Blocks are formed by streets, roads, railroads, streams and other bodies of water, other visible physical and cultural features, and the legal boundaries shown on Census Bureau maps. Patterns, sizes, and shapes of census blocks vary within and between areas. Factors that influence the overall configuration of census blocks include topography, the size and spacing of water features, the land survey system, and the extent, age, type, and density of urban and rural development. At least one side of a census block is a road feature. The census uses extensions from dead-end roads/streets to split oversized polygons into separate blocks; such extensions were made wherever road features protruded into a large polygon and ended within 300 feet of non-road features, such as shorelines and railroads (U.S. Census Bureau 1994).

These considerations indicate that census designations may form property groupings that are useful in delineating property that may experience differential effects from Lake Erie HABs. To further consider this possibility, census groupings were visually inspected.

The U.S. Census Bureau publishes a map of each county depicting the census tracts for each county. Maps showing block groups are available from various sources; for simplicity, this study examined block group maps provided by USA.com (2015) and mappings from the U.S. Census Bureau. The maps for census tracts bordering Lake Erie in counties being considered were visually evaluated to develop an understanding of the relationship between proximity to Lake Erie and the different census groupings. This evaluation indicated census blocks were specified along Lake Erie and census block groups generally consist of groups of blocks that run along shorelines. Further visual inspection identified confirmed these coastal block groups tend to extend inshore about half a mile.

This outcome suggests a process for collecting baseline residential property value data for properties within approximately half a mile of Lake Erie, which is to:

1. Identify census tracts that cover the Lake Erie shoreline in affected counties.
2. Identify coastal block groups within each of these census tracts.
3. Collect the data available from report B25075 reflecting estimated property values by category for each coastal block group.
4. Compile data to calculate estimated aggregate values for residential property values.

This process is visually depicted for block group zero of census tract 97 in Lucas County, Ohio, below (Figure 4-2).

Figure 4-2: Lucas County Tract 97, Block Group 3

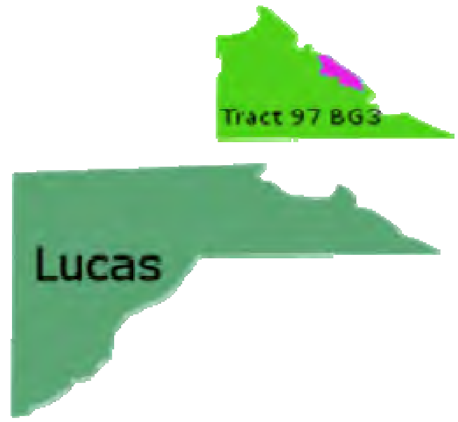


Figure 4-2 also shows block group 3 within census tract 97. After compiling this data, we have data for each identified block group. An example for block group 3, census tract 97 for Lucas County, Ohio, is depicted in Table 4-1.

This process results in a database containing the number of <u>owner occupied</u> homes in each value category for affected U.S. counties located within approximately one-half mile of Lake Erie. The data is summarized in Table 4-2, and indicates residential property in these block groups (that reach the Lake Erie shoreline) has a total value of more than $3 billion.

Table 4-2: Estimated Values of Homes On/Near the Shoreline in Western Basin of Lake Erie

County	Lower Range of Property Value	Upper Range of Property Value	Number of Homes	Number of Homes Valued at $1M or More
Wayne, Michigan	$138,680,000	$174,254,103	897	0
Monroe, Michigan	$491,735,000	$600,380,669	4,331	0
Lucas, Ohio	$449,355,000	$547,690,996	4,004	0
Ottawa, Ohio	$1,086,455,000	$1,262,229,625	5,479	104
Sandusky, Ohio	$57,895,000	$68,879,406	594	0

County	Lower Range of Property Value	Upper Range of Property Value	Number of Homes	Number of Homes Valued at $1M or More
Erie, Ohio	$731,085,000	$879,555,265	4,768	33
Totals	$2,955,205,000	$3,532,990,064	20,073	137

Note: Table includes only the southern tip of Wayne County, Michigan, and the portion of Erie County, Ohio, that lies in the Western Basin of Lake Erie. Upper (lower) ranges are the product of the number of homes times per the upper (lower) range of category from the census.

There are a number of shortcomings to this data. The quality of the self-generated estimates is unclear, the census approach to extrapolating these values induces uncertainty, the implications for homes that are not owner occupied is unclear, properties valued at over $1 million are only identified (not valued), and the data does not differentiate between properties near the shore and those that are farther away.

Given these drawbacks, and the apparent importance of these property values to overall estimates, an additional approach was explored. This approach relied upon an online database available at http://www.zillow.com. Using the Zillow Zestimate interface, it is possible to obtain estimates of nearby property values. Without street addresses, this is only possible by visual inspection of data, as depicted in Figure 4-3 below.

Figure 4-3: Example of Zillow Data from Zestimate Database (http://www.zillow.com)

Due to limitations of the website, this approach was only applied for shoreline properties. In addition to identifying shoreline property values, this approach was used for cross-validation with census estimates. The website http://www.usa.com provides maps of census tracts and block groups that were used to help resolve this visually-collected data to the census block group level. This process can be summarized as:

1. Identify geographic features and roads that mark block group boundaries using the www.usa.com website.
2. Locate block group boundaries in Zillow property value interface.
3. Proceed east to west, recording Zestimate property values and house characteristics for shoreline properties.
4. Terminate at western boundary.
5. Repeat for additional block groups.

Using this approach, the visual data depicted above would be (for example) converted to data that appears in Table 4-3.

Table 4-3: Property Value and Description from Zillow's Zestimate Data (http://www.zillow.com): Lake Erie Shoreline Zone Property Values, Ottawa County, Ohio

Census Tract	Block Group	Location	Borders of Census Tract	Property Type	Property Value	Property Description
508(00) Ohio	1	North of Oak Harbor	West: Big Sand Bay/Park Rd 1/ N Benson Carroll Rd East: County Rd 26/ N Carroll			
508(00) Ohio	1	North of Oak Harbor	Western border of 508(00)	State	$0	Crane Creek State Park
508(00) Ohio	1	North of Oak Harbor		Federal	$0	Ottawa National Wildlife Refuge
508(00) Ohio	1	North of Oak Harbor		Private	$0	Turtle Creek Marina
508(00) Ohio	1	North of Oak Harbor		Residential	$91,000	2 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$135,000	2 bd/2 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$145,000	2 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$119,000	1 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$13,000	2 bd/0.5 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$137,000	2 bd/1.5 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$244,000	2 bd/2 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$124,000	2 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$175,000	2 bd/1.5 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$120,000	1 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$208,000	3 bd/2 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$124,000	2 bd/1.5 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$117,000	2 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$110,000	1 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$5,000	3 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$117,000	2 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$170,000	1 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$123,000	2 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$93,000	1 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$111,000	2 bd/0.5 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$79,000	1 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$80,000	1 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$202,000	3 bd/2 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$268,000	2 bd/2 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$248,000	3 bd/2 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$318,000	4 bd/4 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$25,000	3 bd/2.5 ba

Census Tract	Block Group	Location	Borders of Census Tract	Property Type	Property Value	Property Description
508(00) Ohio	1	North of Oak Harbor		Residential	$412,000	3 bd/2.5 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$185,000	2 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$74,000	1 bd/0.5 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$121,000	1 bd/1 ba
508(00) Ohio	1	North of Oak Harbor		Residential	$26,000	Lot
508(00) Ohio	1	North of Oak Harbor		Residential	$200,000	1 bd/2 ba

There are a number of shortcomings to this approach as well. The manual requirements add effort and also the potential for human error. Regarding the data itself, the Zestimate algorithms used to generate the values are proprietary and therefore not available for inspection. Also, the values are updated frequently, meaning that returning for specific validation is not an option.

Having estimates of the value of U.S. residential property that is potentially exposed to HAB impacts it remains to quantify the value of those impacts. However, doing so requires developing an understanding of the likely magnitude of HABs impacts on residential property values. Table 4-4 lists a number of studies that describe relationships between water quality and property value.

Table 4-4: Property Value Studies

Title	"The Influence of Water Quality on the Housing Price Around Lake Erie"	"Lakeshore Property Values and Water Quality: Evidence from Property Sales in the Mississippi Headwaters Region"	"Marginal Price of Lake Recreation and Aesthetics: An Hedonic Approach"	"Evidence of the Effects of Water Quality on Residential Land Prices"	"Exploring the Hedonic Value of Ambient Water Quality: A Local Watershed-Based Study"	"A Loon on Every Lake: A Hedonic Analysis of Lake Water Quality in the Adirondacks"	"The Spatial Extent of Water Quality Benefits in Urban Housing Markets"
Author	Ara, Irwin, and Haab (2006)	Krysel et al. (2003)	Lansford and Jones (1995)	Leggett and Bockstael (2000)	Poor, Pessagno, and Paul (2007)	Tuttle and Heintzelman (2011)	Walsh, Milon, and Scrogin (2010)
Publication Data	Presented at the American Agricultural Economics Association Annual Meeting, Long Beach, California, July 23–26	Submitted to the Legislative Commission on Minnesota Resources	*Journal of Agricultural and Allied Economics* 27(1):212–223	*Journal of Environmental Economics and Management* 39:121–144	*Ecological Economics* 60(4):797–806	Clarkson University https://www.ecn.ulaval.ca/sites/ecn.ulaval.ca/files/loon lake.pdf	*Land Economics* 87(4):628–644 (2012)
Similarity	Yes	—	—	—	—	—	—
Magnitude	Yes	—	—	—	—	—	—
Water Quality	Yes	Yes	—	Yes	Yes	Yes	Yes
Distance to Lake	Yes	Yes	Yes	—	—	Yes	Yes
Scenic View	—	Yes	Yes	—	—	—	—
Dissolved Oxygen	—	—	—	—	—	—	Yes
Nonpoint	—	—	—	Yes	Yes	—	—

Title	“The Influence of Water Quality on the Housing Price Around Lake Erie”	“Lakeshore Property Values and Water Quality: Evidence from Property Sales in the Mississippi Headwaters Region”	“Marginal Price of Lake Recreation and Aesthetics: An Hedonic Approach”	“Evidence of the Effects of Water Quality on Residential Land Prices"	“Exploring the Hedonic Value of Ambient Water Quality: A Local Watershed-Based Study”	“A Loon on Every Lake: A Hedonic Analysis of Lake Water Quality in the Adirondacks”	“The Spatial Extent of Water Quality Benefits in Urban Housing Markets”
Source Pollution							
Reason for Considering This Work	Studies the link between lake quality and residential development near Lake Erie	Studies implicit prices of water quality—the effects on lakeshore property prices—for lake groups and individual lakes	Study includes distance to lake and scenic view	Study examines water quality and property value	Study examines water quality	Study examines water quality	Study examines proximity effects

When conducting secondary research, a potential approach for identifying the magnitude of impacts is to transfer results from a study of similar effects and properties. For example, the results of Ara et al. which estimated the economic value of changes in water clarity and fecal coliform as a change in housing values, could be transferred to estimate a value for similar impacts on housing values. A difficulty with this approach in the current case is that it changes in secchi disk depth or fecal coliform counts (the environmental quality changes valued in previous research) may not be relevant for HABs. The other studies we could identify are similar in that they focus on environmental conditions, but none has the dramatic impact that is possible from HABs in Lake Erie. An additional important difference results from the intermittency and uncertainty that characterize Lake Erie HABs. By comparison, the effects studied above are for longer-term quality differences. Studies that evaluate the impact of more dramatic, intermittent and uncertain events on property values are described in Table 4-5.

Table 4-5: Studies of Property Values and Natural Disasters

Title	Do Nearby Forest Fires Cause a Reduction in Residential Property Values?	The Effects of Wildfire and Environmental Amenities on Property Values in Northwest Montana, USA	The Effects of Wildfire Disclosure and Occurrence on Property Markets in California	Clear Skies, Dark Waters: The Gulf Oil Spill and the Price of Coastal Condominiums in Alabama
Author	Loomis (2004)	Stetler, Venn, and Calkin (2010)	Troy and Romm (2007)	Siegel, Caudill, and Mixon, Jr. (2013)
Publication data	*Journal of Forest Economics* 10:149–157	*Ecological Economics* 69:2233–2243	Chapter 6 in *Living on the Edge, Volume 6: Economic, Institutional and Management Perspectives on Wildfire Hazard in the Urban Interface*, pp. 1010-1119. Greenwich CT: JAI Press	*Economics and Business Letters* 2(2):42–53
Hedonic	Yes	Yes	Yes	No
Disaster type	Wildfire	Wildfire	Wildfire	Oil spill
Distance decay	No	Yes	Yes	No

Title	Do Nearby Forest Fires Cause a Reduction in Residential Property Values?	The Effects of Wildfire and Environmental Amenities on Property Values in Northwest Montana, USA	The Effects of Wildfire Disclosure and Occurrence on Property Markets in California	Clear Skies, Dark Waters: The Gulf Oil Spill and the Price of Coastal Condominiums in Alabama
Change in quality of environmental amenities	Forest amenity value; aesthetic and recreation	Aesthetic and recreation opportunities	None included in this valuation	None included in this valuation
Reason for considering this work	Hedonic study; homeowners' revised perception of risk	Hedonic study; reduction in sales price of home in disaster area; distance decay	Hedonic study; sale price of home decreased with proximity to a large fire occurring in recent years	Estimated change in property value from environmental disaster

As can be seen in Table 4-5, most of these studies are about the implications of intermittent natural disasters on property value. Although the narrative of these studies is informative, there are a number of important differences between these and HABs, including heightened potential for personal injury and the destruction and (often insurance compensated) rebuilding that can accompany floods, earthquakes, and hurricanes.

This literature review reveals the importance of both water quality and intermittent negative events on property values. However, none of the available studies appear suitably similar to the case of HABs to support transfer. Nevertheless, considering the relatively large value of property that is exposed to HABs, it is important to develop at least a preliminary estimate of value effects. Given the lack of suitable transfer information, the team adopted a "value of lost services" approach to characterize impacts to property values. Specifically, home values are viewed as being composed of the values arising from the flow of services they provide. When HABs intermittently interrupt these services, property owners lose value according to the importance of the services lost, and the length and severity of the interruption.

4.3 POTENTIAL FOR IMPACTS

Implementing this approach requires linking Lake Erie services to home values. As identified earlier, a study by Seiler et al. indicates that otherwise identical properties have a 56 percent higher value if they have a view of Lake Erie. Presuming that "view" proxies for all Lake Erie services, approximately one-third of the value of properties proximate to Lake Erie is explained by Lake Erie services. Steps in this process include the following:

1. Develop estimates of baseline property values for different locations along Lake Erie and distances from the shore using Zillow and the U.S. Census.
2. Calculate an annual cost for each baseline property value.
3. Assign a Lake Erie EcoService percentage to each distance from shore based on literature and professional judgment.
4. Develop a monthly representation of EcoService value based on professional judgment.
5. Specify service interruptions associated with 2011 and 2014 scenarios.
6. Calculate the product to identify the value of lost residential property ecosystem services.

Total value of residential housing stock most likely to be impacted due to future HAB events is calculated to be over $3B. Applying a 10 percent impact to on-shore property values and a 5 percent impact to near-shore values will result in $138.4 million for shoreline properties and $103.7 million for near-shore properties.

The process used to develop property value estimates was described earlier and results in the estimates shown in Table 4-6.

Table 4-6: Value of Property (Stock) at Risk

County or Island	Shoreline Property: Zillow Data	Property about ½ Mile or Less from Shore: U.S. Census Data
Essex County mainland, Ontario	Not available	Not available
Pelee Island, Ontario	Not available	Not available
Wayne County, Michigan (southern tip)	$120M	$150M
Monroe County, Michigan	$200M	$550M
Lucas County, Ohio	$55M	$500M
Ottawa County mainland, Ohio	$236M	$1,000M
Bass Islands, Ottawa County	$176M	$176M
Sandusky County, Ohio	$1.59M	$62M
Erie County mainland, Ohio	$369M	$800M
Kelleys Island, Erie County	$226M	$226M

Note: Shoreline Zillow values for Bass and Kelleys islands exceed all property value estimates from census. For islands, one-half mile values are specified as shoreline values.

Double-counting of shoreline property values is removed by taking the difference between the two to identify values that are near-shore but not on the shore. After applying this process, summing the independent areas results in a total value of residential housing stock of $3.458 billion that could be impacted. Effects, such as those from Table 4-4 can be applied to this value to understand the potential for impacts to the value of this housing stock. For example, applying a 10 percent impact to on-shore value and a 5 percent impact to near-shore values results in $138.4 million for shoreline properties and $103.7 million for near shore properties to total $242.1 million in value. The appropriate impact to apply to these properties has not been studied scientifically and doing so is a recommended next step.

An objective of this study is to identify impacts from the 2011 and 2014 scenarios, and to do so in a representation that allows evaluating reductions (as opposed to elimination) of these impacts. To accomplish this, the value of the housing stock is converted to an annual flow by identifying annual mortgage payments calculated for a 30-year mortgage at 4.13 percent. This results in Table 4-7 show the flow of annual costs:

Table 4-7: Property Value Flow at Risk

County or Island	Shoreline Property	Near Shore not Shoreline
Essex County mainland, Ontario	Not available	Not available
Pelee Island, Ontario	Not available	Not available
Wayne County, Michigan (southern tip)	$119.90M	$30.11M
Monroe County, Michigan	$200.00M	$350.00M
Lucas County, Ohio	$55.29M	$444.70M
Ottawa County mainland, Ohio	$235.60M	$764.40M
Bass Islands, Ottawa County	$176.00M	0
Sandusky County, Ohio	$1.59M	$53.41M
Erie County mainland, Ohio	$369.00M	$431.002M
Kelleys Island, Erie County	$226.60M	$0

In Step 3, the ecosystem service value is specified. Based on results from Seiler et al. an average of one-third of a property's value can be explained by having a view of Lake Erie. There are a couple of complications to employing this empirical result in the specification-based approach employed here. Conceptually, "view" is expected to proxy for a number of lake attributes and the estimated average effect of "view" is expected to vary with properties closer to the lake having more of their value explained by lake services than those that are farther away. To account for this, the annual value of the property (proxied by its annual cost) is multiplied by 0.5 for shoreline properties and 0.2 for properties that are near-shore, but not shoreline. The results are depicted in Table 4-8.

Table 4-8: Ecological Service Value (Flow)

County or Island	Shoreline Property	Near Shore not Shoreline
Essex County mainland, Ontario	Not available	Not available
Pelee Island, Ontario	Not available	Not available
Wayne County, Michigan (southern tip)	$7.043M	$1.769M
Monroe County, Michigan	$11.75M	$20.56M
Lucas County, Ohio	$3.248M	$26.13M
Ottawa County mainland, Ohio	$13.84M	$44.9M
Bass Islands, Ottawa County	$10.34M	$0
Sandusky County, Ohio	$93K	$3.14M
Erie County mainland, Ohio	$21.68M	$25.32M
Kelleys Island, Erie County	$13.31M	$0

An additional consideration arises from the fluctuation in lake services. Over the course of a year, ecosystem services fluctuate. For example, although ice fishing is popular, the great majority of fishing occurs outside the winter months. Because of this, services interruptions during some months are presumably worse than those occurring in other months. To account for this, in Step 4, a weekly representation is developed to account for the expectation that value of lake services fluctuates over the course of a year, as depicted in Table 4-9.

Table 4-9: Property Value Attributable to Lake

Month	Percent of Property Value Attributable to Lake
January	0.02941
February	0.02941
March	0.02941
April	0.02941
May	0.02941
June	0.02941
July Week 1	0.02941
July Week 2	0.02941
July Week 3	0.02941
July Week 4	0.02941
August Week 1	0.05882
August Week 2	0.08824
August Week 3	0.08824
August Week 4	0.08824
September Week 1	0.08824
September Week 2	0.05882
September Week 3	0.02941
September Week 4	0.02941
October	0.02941
November	0.02941
December	0.02941

Conducting this approach requires specifying service interruption scenarios for 2011 and 2014. The service interruption representations of Section 3 are applied. This approach results in estimates of monetized lost property value services of $9.781 million for shoreline property owners in 2011, and $7.087 million for nearshore property owners. For the 2014 HAB event, shoreline property owners are estimated to lose $10.05 million in property value services and nearshore owners are estimated to lose $7.864 million.

Applying the service interruption concept and HAB severity index to the 2011 HAB event results in estimated lost property value services of $9.781 million for shoreline property owners and $7.087 million for nearshore property owners.

For 2014 HAB event, shoreline property owners are estimated to lose $10.05 million in property value services and nearshore owners are estimated to lose $7.864 million.

4.4 SUMMARY OF PROPERTY VALUE RESULTS AND NEXT STEPS

There is no specific study available that identifies the number of properties with value at risk from the presence and severity of HABs, nor are there any studies that scientifically examine the relationship between the presence and severity of HABs and the amount of property value losses. The research presented in Sections 3 and 4 only begins to quantify the presence and severity of HABs and identify the amount of properties that have value at risk and does not fully examine this relationship. A recommended next step would be to develop an econometric model that scientifically-quantifies the presence and severity of HABs and property value losses. Such a study would replace the transfer and scenario-based evaluations conducted for this analysis with a parametrized evaluation of the property value effects of HABs.

Using multiple methods, this section demonstrated that there are likely over $3 billion worth of residential properties that are at risk of damages from HABs. However, there is no single study existing that examines the potential for HABs to negatively impact Lake Erie property values.

A review of the current literature suggests that low water quality can have long-term impacts on property values, and disasters can substantially affect property values for time periods around the significant event. Whether the effects of HABs, which differ in impact every year, are short-term or longer term, the effects of low water quality is an important, open question that warrants future study. Taking some values from the literature on the percentage impact that environmental harms can have on property values serves to illustrate the magnitude that damages from Lake Erie HABs might be: a 5 percent impact to near-shore values and a 10 percent impact to shoreline properties results in $242.1 million in property value impacts. To give another perspective, another approach was taken to illustrate potential residential property losses due to HABs. By considering when and where residential property services, such as views, are impaired by HABs and using the spatial and temporal scenarios described in Section 3 for the 2011 and 2014 HAB events, and making some exploratory assumptions about the temporal pattern of housing service flows, per event losses near $17 million. Clearly, the range of impacts remains uncertain.

Future work could involve a more detailed study that accesses tax assessor data and more fully details property values along the shore and in the nearshore areas where HABs are a risk. Similarly, commercially-available, but costly, data exists on housing sales suitable for identifying the relationship of sale prices to HAB events, HAB risks, and proximity to HABs. A related line of research could also incorporate homeowner preference data from surveys. Since shoreline and nearshore-property owners are important stakeholders, a viable option for addressing the impacts of HABs on property values is to combine survey-based research approaches with formal property value models, as was done for contaminated sediment remediation in Waukegan Harbor (Braden et al, 2004).

In the current effort, although less time-consuming and coarser methods were used, this study was able to clearly demonstrate the substantial value of the housing stock at potential risk of damage from HABs. Coupled with the published evidence that environmental harms affect property values in a variety of similar cases, it is also clear that property is damaged by HABs and their expected occurrence. The substantial potential for damages makes this a key area for future study.

5.0 IMPACTS OF HABS ON TOURISM AND COMMERCE

HABs can potentially affect the closely-related areas of tourism, business profitability, and commercial property values in areas close to western Lake Erie. For example, a well-publicized HAB event would almost certainly cause some tourists to not take trips to an affected area. This would result in reduced revenue for businesses directly related to tourism (e.g. hotels, restaurants, charter boat operators). These businesses would lose revenue and other businesses upstream in the supply chain would potentially suffer as these directly-affected businesses purchased fewer inputs (e.g. hotel and restaurant supplies). Moreover, these directly and indirectly-impacted businesses would be expected to purchase less labor. This could be reflected as reduced new hiring (permanent or temporary) and layoffs. This effect leaves less income available in the local economy leading to a secondary (induced) effect on local businesses from lost local wages.

Ultimately, these sorts of effects would be reflected in business balance sheets as reduced gross revenues and profitability. An additional consideration is that the values of business that are most likely to be affected are tied to their assets and the real estate they occupy. For example, businesses such as marinas, and waterfront hotels and restaurants are not easily converted to some other use. As a result, on-going balance sheet effects would ultimately lead to reductions in commercial real estate values.

In the previous effort, Weicksel and Lupi (2013) reviewed available information on economic impacts to the tourism and charter boat industries. In particular, Weicksel and Lupi compared 2008–2011 direct, indirect, and induced impacts from Tourism Economics in the State of Ohio and the Lake Erie Region of Ohio to algal bloom events. They found that "despite the historically severe algal bloom event in the summer of 2011, the tourism industry statewide and in the Lake Erie region both experienced growth from recent years." Weicksel and Lupi comment that other factors, such as the weather and the "modest but steady recovery" from the economic recession, could have influenced the increased visitation in the summer of 2011. They could identify no immediate economic impacts to the tourism industry caused by HABs, but noted that longer-term or delayed effects may occur in the future. Weicksel and Lupi also found there is no immediate link between charter boat revenue trends and charter captain permit sales and HAB events. Within both the tourism and charter boat industry, Weicksel and Lupi state that more research on the effect of HABs on the tourism is necessary.

In this report, tourists are defined as people coming from outside a shoreline county for single or multiple-day trips.

There are a number of challenges to understanding the implications of changes in tourism from HABs, as listed below:

1. Data sources that indicate the amount of tourism at risk are not available
2. Information about the effects of HABs on tourism is not available
3. Expenditures related to tourism are economic impacts (i.e. not benefits)
4. Impacts and benefits from tourism are generally transfers from one region to another rather than impacts or benefits in a global sense.
5. As described in this section's introduction, there is overlap between changes in tourism, business profitability, and commercial property value.

Considering the first challenge, there are no direct estimates of tourism at risk in the existing literature. For example, although estimates of total expenditures on tourism are available at the county level, these include all visits, many of which are during time periods or for purposes that would not be affected. This limits our ability to reliably characterize the implications of HAB impacts on tourism using this data. To account for this, an approach that starts with an aggregate estimate and pares it down to estimate effects is applied.

The second challenge is that although it seems self-evident that some tourists would forgo trips to the western basin, there are no available estimates of how tourism has been affected by HABs. Given this lack of information, a scenario approach is applied wherein reductions in trips to affected areas during times when HABs were prevalent is applied.

The third challenge relates to things that are detailed in Section 3. To briefly recap, economics makes an important distinction between economic benefits and economic impacts.

- *Economic benefits* can be thought of as what an individual, or individuals aggregated up to the societal level, would be willing to pay for a different state of the world.
- *Economic impacts* refer to changes in expenditures. The relationship between benefits and impacts is not always readily apparent.

On the producer side (which this section studies), consider a restaurateur who has lost $1,000 in revenue due to a HAB. The restaurateur would have a willingness to pay to recover that revenue; however, the willingness to pay is not the lost revenue, but (roughly speaking) the lost profit on that revenue. Here again, the lost profit is not generally easily identifiable. Understanding what was lost requires knowing what expenditures were foregone, which depends on the operation's variable cost situation with respect to employees (salaried or not) already purchased foodstuffs (perishable or not) and utilities. To address this issue, the approach taken here is to identify economic impacts (i.e. changes in expenditures) under various scenarios first and then to characterize benefits associated with those changes.

The fourth enumerated challenge with identifying the economic benefits of changes in tourism notes that in most cases, changes in tourism are transfers in activity from one area to another. For example, a tourist who forgoes a trip to the western basin could go instead to the central basin, Mount Rushmore, or any number of other places. The clear implication is that what some businesses lose others gain. To address this, we define an affected region where benefits occur. As defined for this investigation, economic impacts occur when visitors from outside western basin coastal counties visit and spend money within these counties. Benefits accrue from these visitors direct and downstream expenditures in the local economy.

The final enumerated challenge refers to the previously-described link between tourism, business profitability, and commercial property values. Changes in tourism affect revenues, which affect business profitability, which affects commercial property value. As challenge 3 describes, changes in benefits in one sector enables a change in benefits to a related sector. It is useful to disentangle benefits from changes in expenditures, and the approach taken here is to identify both. We judge there is a high risk that identifying both impacts to profitability and to commercial property value will result in double-counting; the focus is instead to characterize potential impacts to business profitability.

The remainder of this section presents the detailed methods and results. Due to differences in available data, slightly different methods are applied for Ohio, Michigan, and Canada; thus each of these are described individually.

5.1 OHIO TOURISM

As different sorts of information is available by region, varying approaches are applied. This sub-section explores potential effects in Lucas, Ottawa, Sandusky, and Erie counties, which are depicted in Figure 5-1.

The approach relies on estimates of expenditures per trip and a breakdown of these expenditures by what they are spent on in Ohio.

Figure 5-1: Ohio Counties, United States

5.1.1 Characterization of Expenditures

Understanding potential impacts to tourism requires characterizing per-day expenditures by trip type. Expenditure and trip data in Ohio is collected from two primary sources: Longwoods International (2014) and Tourism Economics (2014). Since 1999, Longwoods International has conducted a program of tourism research for the Ohio Division of Travel and Tourism. This program includes annual estimates of the "volume, characteristics, and profile of overnight and day travel to and in Ohio." Tourism Economics takes the visitor expenditures by sector from Longwoods International's survey and adjusts the levels based on known measures of tourism activity. Tourism Economics also uses data from U.S. Department of Commerce Office of Travel & Tourism Industries' Survey of International Air Travelers.

According to Longwoods International and Tourism Economics, Ohio day visitors spent $110 per visitor in 2013. This visitor spending accounted for 57.4 percent of total Ohio visitor spending, while these visitor's trips accounted for 80 percent of total Ohio visitors. Of marketable Ohio day trips, 33 percent come from Toledo and Cleveland, which are Lake Erie shoreline areas.

Ohio overnight visitors spent approximately $335 per day in 2013. This spending accounted for 42.6 percent of total Ohio visitor spending. Overnight visitors accounted for 20 percent of total Ohio visitors in 2013. Of the overnight visitors, 20 percent of marketable trips are with friends and relatives. The average for overnight trips in 2013 was 3.2 nights per trip, and the average number of visitors per travel party in 2013 was 3.4 visitors. In 2013, 18 percent of overnight visitors stated that they went to a lakeside beach.

Table 5-1 presents the breakdown of spending by Ohio visitors in 2013 (Tourism Economics 2014). Transportation and food and beverage expenditures comprise the majority of spending. This is because both day and overnight visitors spend money in these categories. Lodging only accounts for 11 percent of spending, while retail and recreation expenditures is almost one-third of Ohio visitor spending.

Table 5-1: Breakdown of Ohio Visitor spending

Expenditure Category	Percent of Total Spending
Lodging	11%
Food and Beverage	25%
Retail	14%
Recreation	16%
Transportation	31%
Air	2%

This breakdown is the base of spending for all visitors. For this analysis, these expenditure rates are further broken down by trip type and average per-day expenditures. For example, day visitors spend $110 per visitor. Because these visitors come from nearby, this $110 does not include lodging or air travel expenditures. Overnight visitors spend an average of $335 per visit per person, with costs varying between whether visitors stay with friends/family or in commercial lodging. For the purposes of this study, we presume overnight visitors who stay with friends and family do not spend money on lodging. In addition, they spend slightly less on each of the other spending categories than what is demonstrated in Table 5-1. When these specifications are made, overnight visitors who stay with friends and family spend an average of $243.90.

Overnight visitors who stay in hotels, bed and breakfast establishments, and at other commercial lodging places are not only impacted by lodging costs, but are also more likely to spend about 10 percent more on food and beverages than overnight visitors who stay with friends and family. This results in an average of $357.58 per day per overnight visitor (who pays for lodging).

Table 5-2 presents the expenditure breakdown by trip type. Day visitors spend the most on transportation, followed by food and beverage and recreation. Overnight visitors who stay with relatives and friends spend the most on transportation, followed by food and beverage. Overnight visitors who stay at hotels and bed and breakfast establishments spend the most on lodging. The three groups of overnight visitors spend almost the same on transportation as they do food and beverage. The average spending across the three overnight trip categories is $335 per visitor per day.

Table 5-2: Expenditures by Day and Trip Type

Expenditure Category	Day Visitors	Overnight Visitors Stay At: Relatives/ Friends	Hotel	Bed and Breakfast
Lodging	—	—	$105.20	$105.20
Food and Beverage	$32.03	$76.28	$84.76	$84.76
Retail	$18.10	$38.32	$38.32	$38.32
Recreation	$20.76	$43.95	$43.95	$43.95
Transportation	$39.11	$82.81	$82.81	$82.81
Air	—	$2.53	$2.53	$2.53
Average Spending per Visitor	$110.00	$243.90	$357.58	$357.58

5.1.2 The Economic Impact of Tourist Days

As depicted in Table 5-2, per-day expenditures vary by type of visit. In order to characterize the ultimate implications of changes in tourism and to use available tourism information, these expenditures must be further evaluated in terms of their implications for additional expenditures. To do so, we apply a mathematical-economic technique called Input/Output Analysis (Leontief 1986). Input/Output Analysis can be used to assess the effects of direct changes in expenditures (such as those in Table 5-2) in a particular economic system (e.g., town, county, state, region, or national level) in terms of indirect and induced changes that result. Input-output analysis includes effects across the following three categories.

- *Direct impacts*, which represent the impacts from the industry being evaluated (e.g., sales at hotels).
- *Indirect impacts*, which are the inter-industry transactions between the supplying industries and the directly-affected industries (e.g., maintenance and repair of hotels).
- *Induced impacts*, which reflect the local spending from the directly and indirectly-affected industry sectors (e.g., purchases at local restaurants and grocery stores by employees working at hotels).

To estimate the direct, indirect, and induced impacts, the analysis uses IMPLAN (IMPLAN, 2014) with data and equations from shoreline ZIP codes in Lucas County. IMPLAN contains detailed input-output information on more than 500 economic sectors at the national, state, county, and ZIP code level.

Each expenditure category in Table 5-2 comprises a variety of sectors. Lodging includes hotels (NAICS 721110) or bed and breakfast (NAICS 721191) expenditures. The food and beverage category includes full-service restaurants (NAICS 722511), limited-service restaurants (NAICS 722513), and all other food and drinking places (e.g., mobile food concession stands – NAICS 722330). Retail expenditures are spent at food and beverage stores (e.g., fish and seafood markets – NAICS

445220), health and personal care stores (e.g., CVS – NAICS 446110), motor vehicle and parts dealers (e.g., boat dealers – NAICS 441222), clothing stores (e.g., family clothing stores – NAICS 448140), and general merchandise stores (e.g., Walmart – NAICS 452112).

Recreation expenditures include expenditures at places like performing arts companies (NAICS 711110 and 711130), museums (NAICS 712110), zoos (NAICS 712130), parks (NAICS 712190), amusement parks (NAICS 713120), gambling industries (NAICS 713290 and 713210) (which are present in shoreline ZIP codes in Lucas County), and marinas (NAICS 713930). Transportation includes expenditures at gas stations (NAICS 447110 and 447190), water transportation (e.g., Great Lakes passenger transportation – NAICS 483114), transit and ground passenger transportation (e.g., bus operations – NAICS 485210), and scenic and sightseeing transportation (NAICS 487210).

To use the IMPLAN model, per-trip expenditures by category from Table 5-2 are apportioned over these sectors at the rate that they appear in the IMPLAN data and then simulations are conducted using IMPLAN to identify per-trip indirect and induced effects as depicted in Tables 5-3 and 5-4, respectively.

Table 5-3: Mid-Value Expenditures by Trip Type, Indirect Expenditures

Expenditure Category	Day Visitors	Overnight Visitors Stay At		
		Relatives/ Friends	Hotel	Bed and Breakfast
Lodging	—	—	0.3206	0.3206
Food and Beverage	0.4711	1.122	1.247	1.247
Retail	2.706	5.729	5.729	5.729
Recreation	0.3258	0.6897	0.6897	0.6897
Transportation	0.6556	1.43	1.43	1.43
Other Commercial	15.65	34.71	50.89	50.89
Average Spending per Visitor	19.81	43.68	60.3	60.3

Table 5-4: Mid-Value Expenditures by Trip Type, Induced Expenditures

Expenditure Category	Day Visitors	Overnight Visitors Stay At		
		Relatives/ Friends	Hotel	Bed and Breakfast
Lodging	—	—	0.4134	0.4134
Food and Beverage	0.9595	2.285	2.539	2.539
Retail	6.171	13.07	13.07	13.07
Recreation	0.3168	0.6707	0.6707	0.6707
Transportation	0.1967	0.4291	0.4291	0.4291
Other Commercial	12.88	28.56	41.88	41.88
Average Spending per Visitor	20.53	45.01	58.99	58.99

As these tables indicate, indirect and induced effects are comparable in magnitude for equivalent trip types. The sum of these is a fraction of direct effects. For example indirect and induced effects sum to approximately $120 per-day for overnight trips whereas the comparable direct expenditures are over $350. The largest category for indirect and induced impacts is “other commercial sectors.” This category incorporates a large number of categories with low impacts including the following:

- Real estate
- Owner-occupied dwellings
- Hospitals and offices of physicians and dentists
- Postal service
- Advertising, public relations, and related services
- Waste management and remediation services
- Truck transportation
- Automotive repair and maintenance shops
- Maintenance and repair of residential structures
- Landscaping and horticultural services
- Warehousing and storage
- Legal services
- Financial services (e.g., bookkeeping and payroll services).

Impacts occur in these commercial sectors according to expenditure relationships with direct effects. For example, the real estate sector includes commercial property managing. With a decrease in spending at food and beverage places, as well as hotels, the commercial property managing sector will incur a decrease in output as well.

Owner-occupied dwellings, dwellings owned by the households that live in them, experience the highest induced effects. This is because of lower household spending due to decrease in output from the directly-affected industries (e.g., hotels and restaurants). Hospitals and offices of physicians and dentists experience the second-highest induced impacts. This could be because households have less money to spend on things like routine medical checkups.

5.1.3 Ohio Tourism at Risk

The approach for estimating tourist trips and dollars at risk in Ohio begins with estimates of by county tourism economic impacts in 2013. These are available from Tourism Economics (20014). According to Tourism Economics in 2013:

- Lucas County received $1.16 billion to $2.08 billion in tourism-related sales (midpoint $1.62 billion).
- Ottawa County received $243 million to $569 million in tourism-related sales (midpoint $406 million).
- Sandusky County received $5.3 million to $243 million in tourism-related sales ($124 million).
- Erie County received $1.16 billion to $2.08 billion in tourism-related sales (midpoint $1.62 billion).

To consider the potential implications of HABs, it is useful to represent these economic impacts as a number of trips by type (i.e. day trip or overnight). To do this, a composite trip is developed. This is the economic impact of an "average" trip that represents the direct, indirect, and induced effects of all trip types. Table 5-5 presents the percent of trips by type and their average economic impact per day.

Table 5-5: Visit Proportion and Economic Impacts

Visitor Type	Percent of Total Days	Economic Impact
Day Visitors	80%	$150.30
Relatives/Friends	4%	$332.60
Hotel	15%	$476.90
Bed and Breakfast	1%	$476.90

As identified earlier, day visitors account for 80 percent of total visits, and overnight visitors account for 20 percent of total visits. Of the total, 4 percent stay with friends and family. Using this approach, the economic impact of an average tourist day (which is composed of the information in Table 5-5) is estimated to be $209.90. This is consistent with the following trips by county and type in Table 5-6.

Table 5-6: Visit Proportion and Economic Impacts

County	Day	Friends	Hotel	B&B
Lucas	6.175M	308.80K	1.158M	77.19K
Ottawa	1.548M	77.38K	290.2K	19.35K
Sandusky	472.7K	23.63K	88.62K	5,908
Erie	6.175M	308.80K	1.158M	77.19K

This approach provides estimates of tourist trips from outside Ohio's western basin shoreline counties. These are further evaluated to identify trips that would potentially be affected by HABs, which would be trips that are related to Lake Erie and occurring during the time period when they could be affected by HABs. Longwoods International (2014) reports that 18 percent of Ohio tourist trips are visits to lakeside beaches and that hotel stays for business and pleasure are evenly distributed throughout the year. In this case, the late summer and early fall account for 12 percent of annual days. Assuming that lakeside trips are related to Lake Erie and that trips related to Lake Erie occur at the same rate as hotel stays, these can be used as factors to predict tourist days that are at risk from HABs by multiplying trips by 2.16 percent (0.18*0.12 = 0.0216). However, of greater interest is the percent of total trips to *shoreline* counties that occur during late summer and early fall *and* are in some way related to Lake Erie. The appropriate percentage is not available and 10 percent is specified as the upper end in the sensitivity-based approach.

As can be seen in Table 5-7 and 5-8, this process results in estimates of Ohio tourist dollars at risk that range from $66 million to $305 million.

Table 5-7: Mid-Value of Dollars at Risk, Trips Taken to Lake Erie

	Lucas	Ottawa	Sandusky	Erie
Lodging	2.826M	708.2K	216.3K	2.826M
Food and Beverage	5.884M	1.475M	450.4K	5.884M
Retail	4.315M	1.082M	330.3K	4.315M
Recreation	3.424M	858K	262.1K	3.424M
Transportation	6.479M	1.624M	495.9K	6.479M
Other Commercial	5.447M	1.365M	416.9K	5.447M
Totals	28.37M	7.111M	2.172M	28.37M

Table 5-8: High-End Value of Dollars at Risk, Trips Taken to Lake Erie

	Lucas	Ottawa	Sandusky	Erie
Lodging	13.08M	3.279M	1.001M	13.08M
Food and Beverage	27.24M	6.827M	2.085M	27.24M
Retail	19.98M	5.007M	1.529M	19.98M
Recreation	15.85M	3.972M	1.213M	15.85M
Transportation	30M	7.517M	2.296M	30M
Other Commercial	25.22M	6.32M	1.93M	25.22M
Totals	131.4M	32.92M	10.06M	131.4M

5.1.4 *Ohio Tourism Benefits*

Given this estimated amount of tourism at risk it remains to characterize diverted tourism trips/dollars and to quantify the related lost profits. Lost tourism is quantified for the 2011, 2014, and lagged/halo scenarios. For the within-year scenarios, there is no information available to determine the amount that was diverted (or would be diverted in similar years). Unlike impacts to property value and recreation, these are specified to be less directly affected and the general, sensitivity-based approach is applied. Here, it is assumed that western basin tourists become aware of the bloom and are able to change plans and reservations. For the simplest calculation, the percent of diverted trips is specified as 5 percent for the low end and 10 percent for the high end. No variation across trip type is specified. This process results in the estimates of losses specified in Tables 5-9 and 5-10.

Table 5-9: Low-end Revenue Lost

	Lucas	Ottawa	Sandusky	Erie
Lodging	141K	35K	10K	141K
Food and Beverage	294K	74K	22K	294K
Retail	216K	54K	16K	216K
Recreation	171K	43K	13K	171K
Transportation	324K	81K	25K	324K
Other Commercial	272K	68K	21K	272K
Totals	1.419M	356K	109K	1.419M

Based on this approach Ohio tourist dollar losses on the low end total approximately $3 million.

Ohio tourist dollars at risk range from $66M million to $305 million. Associated higher-end estimate of lost profits are $20.79 million, and lower end of lost profits are $165,000.

Table 5-10: High-End Revenue Lost

	Lucas	Ottawa	Sandusky	Erie
Lodging	1.308M	328K	100K	1.308M
Food and Beverage	2.724M	683K	208K	2.724M
Retail	1.98M	500K	153K	1.98M
Recreation	1.585M	397K	121K	1.585M
Transportation	3.0M	751K	229K	3.0M
Other Commercial	2.522M	631K	193K	2.522M
Totals	13.1M	3.292M	1.001M	13.1M

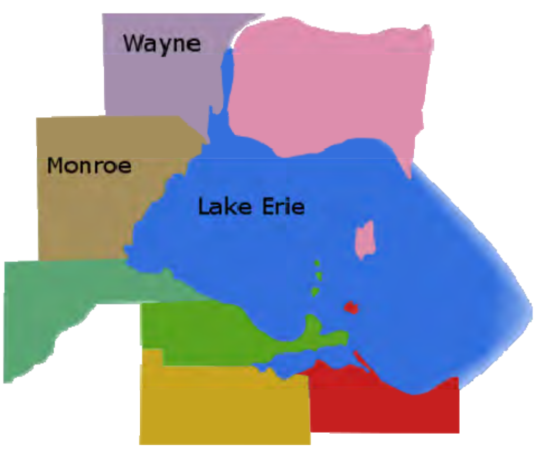
On the high end, they exceed $30 million. Having these estimates of lost revenue, it remains to consider the benefits associated with these. As described in Section 5, changes in profit are the best-available representation of the benefit (willingness to pay) for changes in revenue. Profit represents the difference between costs and revenues.

The National Restaurant Association (2015) reported that in 2013–2014 restaurants earned from 4.1 to 6.3 percent median income on revenue before taxes. This figure represents an average over the course of a year and includes expenses that can't be adjusted, such as certain salaries and building costs. Marginal changes with restaurant operations are expected to have much higher impacts. For example, according to the "2010 Operations Report" published by the National Restaurant Association and Deloitte & Touche, both full-service and limited-service restaurants spent 32 percent of every dollar on food and beverages. Labor costs account for 29 to 33 percent of sales, and restaurant occupancy costs accounted for 8 percent during 2010 (Locsin 2015). An implication is that the loss of a marginal customer (where labor and operating costs don't change) could have a profit impact of only 5 percent (food and beverage costs) or as high as 68 percent. Applying 68 percent as the high end and 5 percent as the low end results in high-end lost profits of $20.79 million and low-end estimates of $165,000. These rough estimates apply for years with significant blooms including 2011 and 2014. Considering lagged effects, these would occur as tourists forego trips in years with lesser blooms and are expected to be lower.

5.2 MICHIGAN TOURISM

Michigan counties that are adjacent to Lake Erie include Wayne County and Monroe County. These counties are depicted in Figure 5-2 and show that a small portion of Wayne County is exposed to Lake Erie shoreline.

Figure 5-2: Michigan Counties, United States



Also, the evaluation of impacts indicates in Section 3 that Wayne County has little exposure to the HABs. For this reason, this assessment focuses on Monroe County and does not evaluate Wayne. The evaluation for Monroe County begins with the total number of visitors that make it a destination annually. This number is approximately 14 million people (Monroe County Planning Department and Commission, 2013). Similar to Ohio, we next determine the number and types of trips that would sum to 14 million visitors to Monroe County, Michigan. To do so, we combine the percent visitors who stay overnight versus day-trippers, the percentage coming from outside the affected area, the percentage who go to Lake Erie, and the affected time period. Data for these inputs comes from the 2010 Southeast Michigan visitor profiles (D.K. Shifflet & Associates Ltd. [DKSA], 2011). DKSA conducted its Travel Performance/MonitorSM study, which measures the travel behavior of U.S. residents. Since 1991, the study has contacted 50,000 distinct U.S. households monthly. The following data are for southeast Michigan, which includes Monroe County.

Day trips account for 41 percent of total tourist days in southeast Michigan, while overnight visitors account for the remaining 59 percent. Again, overnight visitors are categorized as staying with family or friends, staying at a hotel, or staying at a bed and breakfast.

According to DKSA (2011), 51 percent of leisure stays are in a private home. This analysis specifies this means they stay with friends and family. Hotel stays accounts for 33 percent of overnight trips, while the remaining 16 percent is specified to stay at bed and breakfast establishments (other paid and all other accommodations in DSKA 2011). When combined, day trips account for 41 percent of total annual visitor days, overnight trips spent with friends and family account for 30 percent of annual days, overnight trips spent at a hotel are 20 percent of total annual days, and overnight trips spent at a bed and breakfast are over 9 percent of total annual days to Monroe County.

In Michigan, a total of $24.78 million in tourism economic impact is at risk. This is associated with high-end lost profits of $1.685 million and low-end estimates of $124,000.

As with Ohio, only a certain percentage of day trips are specified to come from outside the affected area. We exclude trips originating from Detroit, Michigan (26.0 percent), and Toledo, Ohio (2.2 percent) to conclude 71.8 percent of day trips originate from outside the affected area. Also, not all visitors to Monroe County visit Lake Erie. DSKA (2011) states only 2 percent of southeast Michigan visitors go to the beach or waterfront and 1 percent boat or sail. The analysis combines these percentages and specifies the percentage of visitors who travel to Lake Erie (3 percent). In addition, the number of visitors who take leisure trips in the late summer/early fall (August and September) to Michigan is 20 percent (DKSA 2011).

Multiplying the 14 million visitors by the type of visit (day and overnight), the percentage coming from outside the affected area, the percent going to Lake Erie, and the trips during the affected time period results in a total of 74,288 trips that are at risk from the presence of HABs.

To calculate the tourist dollars at risk, we multiply trip expenditures by corresponding trip type (day or night). The average day trip costs $135, while the average number of people per trip (party) is 1.96. To calculate the average dollars spent per day visitor, we divide $135 by 1.96, to equal $68.88. Those staying with friends and family average around $437 per trip, while the average of parties staying in a hotel is $827. The average of those staying in other paid accommodations is $975. When divided by 1.96 people per travel party, the following per visitor spending is used for each type of overnight trip:

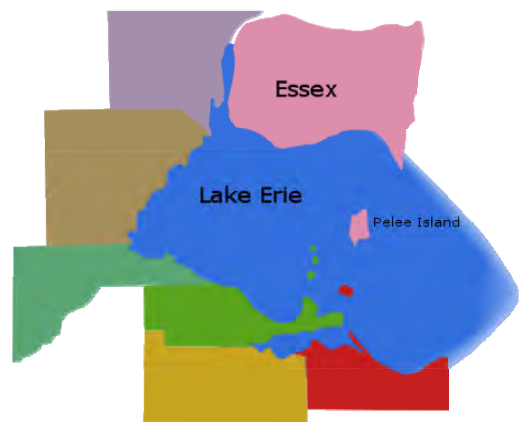
- Overnight—staying with family or friends: $222.96
- Overnight—staying at a hotel: $421.94
- Overnight—staying at a bed and breakfast: $497.45

The trips by type are multiplied by the expenditures by type to estimate "direct" tourist dollars at risk in Monroe County. Over the affected time period, there are 24,728 day trips, 25,276 overnight trips that stay with family, 16,355 overnight trips staying at a hotel, and 7,930 overnight trips staying at a bed and breakfast inn at-risk. These 74,288 trips spend a total of $18.2 million. To calculate indirect and induced expenditures at risk, the ratios from Lucas County shoreline ZIP codes are applied. With these included, a total of $24.78 million in tourism economic impact is at risk in Monroe County. Using the approach and rationale for disentangling profit applied for Ohio, this results in high-end lost profits of $1.685 million and low-end estimates of $124,000. These rough estimates apply for years with significant blooms including 2011 and 2014. Considering lagged effects, these would occur as tourists forgo trips in years without blooms.

5.3 CANADA TOURISM

The primary geographic region at risk for tourist dollar losses in Canada is Essex County. As depicted in Figure 5-3, Essex County has a significant amount of shoreline on the northern portion of the western basin and Pelee Island is part of Essex County.

Figure 5-3: Essex County, Canada



The approach for estimating tourist trips and dollars at risk for Essex County, Canada, starts with the total number of visitors who make Essex County an annual destination. This number is approximately 4.8 million people (Ontario Ministry of Tourism, Culture and Sport, 2014). The first step is to determine the number and types of trips that would sum to 4.8 million visitors to Essex County, Canada. To do so, we combine the percent of visitors who stay overnight versus day-trippers, the percent traveling from outside the affected area, the percent that go to Lake Erie, and the affected time period. Data for these inputs comes from the 2012 Essex County visitor profiles (Ontario Ministry of Tourism, Culture and Sport, 2014). The data is part of the Ontario Ministry of Tourism, Culture and Sport's Travel Survey of the Residents of Canada, which is a supplement to monthly Labour Force Survey, and the International Travel Survey, which is distributed at land and air entry points.

Day trips account for 69 percent of total trips to Essex County, and overnight visitors account for the remaining 31 percent of total visits. This analysis categorizes overnight visitors into three different categories:

1. Overnight—staying with family or friends
2. Overnight—staying at a hotel
3. Overnight—staying at a bed and breakfast.

According to the Ontario Ministry of Tourism (2014), 61.3 percent of overnight trips are in unpaid accommodations, like a private home. This analysis concludes this means they stay with friends and family. Commercial (hotel) stays account for 26.4 percent of overnight trips. The remaining 12.3 percent is specified to stay at bed and breakfast establishments. When combined, day trips account for 69 percent of total annual visitor trips, overnight trips spent with friends and family account for 19 percent of annual trips, overnight trips spent at a hotel are 8 percent of total annual trips, and overnight trips spent at a bed and breakfast are over 4 percent of total annual trips to Essex County, Canada.

Only a certain percentage of day trips are specified to come from outside the affected area. We exclude trips originating from Amherstburg, Kingsville, Leamington, and Wheatley because these four areas are adjacent to Lake Erie. They account for 17.1 percent of the Essex County population (Statistics Canada 2015). This means that, of the day trips, 82.9 percent originate from outside the affected area.

Canadian tourism economic impacts total of $17.3 million with high and low profitability impacts ranging from $1.6 million to $59,000.

Not all visitors to Essex County, Canada, visit Lake Erie. Ontario Ministry of Tourism, Culture and Sport (2014) states approximately 13 percent of visitors in Essex County participate in outdoor/sports activities and approximately 3 percent go to national or provincial nature parks. The analysis combines these percentages and specifies this is the percentage of visitors who go to Lake Erie (16 percent). In addition, the number of visitors who take trips in the summer (July through end of September) to Essex County is 31 percent (Ontario Ministry of Tourism, Culture and Sport, 2014). Assuming these summer trips are evenly distributed across the three months means that 21 percent of trips occur in the late summer or early fall (August and September).

Multiplying the 4.8 million visitors by the type of visit (day and overnight), the percentage coming from outside the affected area, the percent going to Lake Erie, and the trips during the affected time period results in a total of 140,553 trips that are at risk from the presence of HABs. To calculate the tourist dollars at risk, we multiply the trips by trip-type expenditures (day or night). The average spending per trip for day visitors is $72. The average spending for overnight visitors is $212 (Ontario Ministry of Tourism, Culture and Sport, 2014). Overnight visitors spend a varying amount depending on accommodations. We assume overnight visitors who stay with family do not pay for lodging, and, therefore, spend less per trip. Overnight visitors staying in a hotel or bed and breakfast spend more than overnight visitors staying with family and friends because they must pay for lodging. The following per visitor spending is used for each type of overnight trip and is based on the spending pattern in Ontario Ministry of Tourism, Culture and Sport (2014):

- Overnight—staying with family or friends: $157.49
- Overnight—staying at a hotel: $308.47
- Overnight—staying at a bed and breakfast: $308.47

Multiplying the trips by type, by the expenditures by type, calculates the tourist dollars at risk in Essex County, Canada. Over the affected time period, there are 90,554 day trips, 30,649 overnight trips that stay with family, 13,200 overnight trips staying at a hotel, and 6,150 overnight trips staying at a bed and breakfast inn at-risk. These 140,553 trips spend a total of $17.3 million. Applying the Lucas County multipliers and profitability approach used previously, the area sees an estimated $1.6 million to $59,000 in benefits. These rough estimates apply for years with significant blooms including 2011 and 2014 Considering lagged effects, these would occur as tourists forgo trips in years with less significant blooms and are expected to be lower.

5.4 SUMMARY AND NEXT STEPS

HABs can potentially affect the closely-related areas of tourism, business profitability, and commercial property values in areas close to western Lake Erie, which can directly translate into lost income and profits and constitute a potentially large economic damage associated with HABs. Section 5 showed that counties adjacent to western Lake Erie experience millions of out of town trips and billions of dollars in tourism expenditures annually. Although not all of this is directly related to Lake Erie, and only a portion occurs during HAB-affected time periods, it is clear that significant tourism revenue is at risk due to HABs. A portion of this revenue is profits. Not losing these profits would constitute a direct benefit, which would also be reflected in the value of businesses and commercial property. Section 5 reported on efforts to make some assumptions and use existing readily available data to assess these economic losses. However, it was noted that very little specific and useful data is available and more thorough research is recommended.

There are numerous parameters relating the presence and severity of HABs to changes in tourist activity that are not well understood and that were specified as defined scenarios for this analysis. A key next step would be to develop scientifically-based evaluations of the following:

- The relationship between the percent of total late summer and early trips to counties that border western Lake Erie and those trips that are related to Lake Erie.
- Develop a scientific evaluation of the relationship between the presence of HABs and diverted tourist trips.
- The relationship between the types of trips that are diverted because of the severity of HABs, where those trips are diverted to, and the amount of spending on those diverted trips.

Despite these limitations, Section 5 illustrated that tourist dollars in Ohio at risk from HABs range from $66 million to $305 million. Associated high-end lost profits are $21 million, but could be under $1 million. In Michigan, about $25 million in tourism economic impact was judged to be at risk, which was associated with lost profits of $1.7 million on the high end. For Canada, impacts at risk were about $17 million with high and low-profitability impacts ranging from $1.6 million to $59,000. Again, deriving these numbers from readily available data requires numerous assumptions, and, given the large ranges of uncertainty, warrant further refinement. Moreover, these rough estimates apply only for years with significant blooms such as 2011 and 2014. As for lagged effects, they would occur as tourists forego trips in years with lesser blooms and are expected to be lower, but there is currently no available data to quantify them.

6.0 IMPACTS OF HABS ON FISHING, BEACH-GOING, AND BOATING

6.1 HAB EFFECTS ON RECREATION

People use Lake Erie waters for a variety of recreational activities, including fishing, beach-going, and boating. Weicksel and Lupi (2013) studied effects to beach recreation and fishing, but did not study boating effects.

For beach-going, Weicksel and Lupi (2013) noted that in 2011, the Ohio Department of Health issued advisories at four beaches in Lake Erie's western basin: Battery Park, Lion Park, Kelleys Island State Park and Maumee Bay State Park. Based on coefficients from a beach site closure model and available information on affected trips, a total of $1.3 million in losses was estimated for Maumee Bay State Park in 2011.

Phase I study further noted an estimate of 1.8 million day trips to 15 Ohio beaches in 1997 (from Murray et al. 2001), but did not estimate the value of trips lost to other sites because of a lack of specific information about the number of trips to these sites. Weicksel and Lupi (2013) also noted that even without closures, HABs can result in algae in the water and on the shore. Empirical evidence (Weicksel 2012) was cited indicating recreationists are willing to incur costs to avoid excess algae. Although this effect was not quantified, it was cited as evidence for values arising from lower quality trips.

For fishing, Weicksel and Lupi (2103) noted that HABs could lead to reduced catch rates and less desirable eating. The study found losses to recreational fishing caused by increases in HAB severity in western Lake Erie were $2.4 million in Ohio. There seems to be "a negative relationship between microcystis biovolume in Lake Erie and recreational fishing trips taken to [Ohio Fishing] Districts 1 and 2."

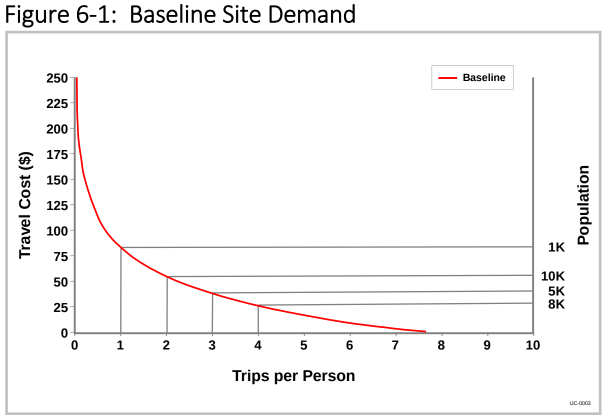
Weicksel and Lupi (2013) were unable to quantify HAB-related impacts to non-fishing boating trips. Weicksel and Lupi noted that "The quality of non-fishing boat trips on Lake Erie could be affected by HABs either by spoiled aesthetics or the risk of contact with algal toxins from wave action, wind-blown or splashing water."

6.2 METHODS FOR IDENTIFYING RECREATIONAL BENEFITS - OVERVIEW

The Phase I effort identified a number of recreation-related benefits of HAB reductions and also noted data limitations precluded identifying certain other benefits. For example, the effects of beach closures where lost trips estimates were not available and the effects of reductions in trip quality were not evaluated. This study suffers from the same information limitations. To partially circumvent this issue, this study uses site-choice simulations for beach-going and fishing. These simulations use relevant available information, including demand functions, trips information, known closures, and the quality reductions identified in Section 3.2.

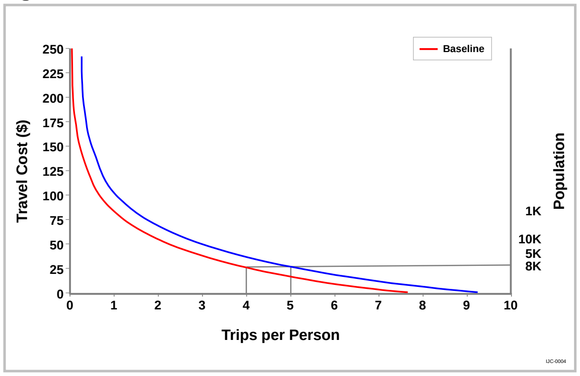
This framework is an operationalized population-level version of the demand concepts described in Section 3.2. The baseline demand is depicted in Figure 6-1.

Figure 6-1: Baseline Site Demand



In this population depiction, the number of people experiencing each travel cost is introduced on the right axis and used to characterize aggregate behaviors. Specifically, under baseline conditions, 1,000 people average one trip to the site, 10,000 people average two trips, 5,000 people average three trips, and 8,000 people average four trips for a total of 68,000 trips to this site over this time period. Under the counterfactual condition (i.e., the 2011 and 2014 HABs do not occur), the positive change in quality results in outward movement of the demand curve, as depicted in Figure 6-2.

Figure 6-2: Site Demand with Reduced HABs



This outward movement on the demand curve results in more trips from each origin and more trips to the site. As seen in Figure 6-2, the population center with 8,000 recreationists was previously averaging four trips per visitor, and was responsible for 32,000 trips to the site. This group is now averaging five trips to this site per visitor and is responsible for 40,000 trips to the site. This outward shift in demand is also associated with higher welfare (willingness-to-pay) for all trips. At the individual level, willingness to pay is calculated as described in Section 3.2.1 (area between curves and above expenditures). To identify societal benefits, it is calculated for all individuals (and sites), then summed to get societal willingness to pay. In addition to identifying the impacts of marginal quality changes, this approach can be used to identify the effects of site closures.

This approach also captures important effects that are challenging to characterize with a less comprehensive framework. For example, apportioning an estimate of all trips over sites allows assessing trip quantity effects at each site. Specifying the by-week and county quality reductions allows capturing marginal quality effects. Moreover, this approach is extendable; for example, differential changes in site quality (e.g., suppose future effects were half as bad as 2011 and 2014, rather than being eliminated).

Although this is a relatively sophisticated form of transfer that employs a function rather than a point estimate, it is still a transfer of results from studies of different phenomena. Only primary recreational demand studies can characterize implications of an important and dynamic impact like Lake Erie HABs. The selection of transfer studies, integration of baseline trips and behavior, as well as the modeled response to the HABs, all require a good deal of expert judgment. The approach to trip taking and welfare simulation is similar. However, the functional results from methodologies of this sort do not have the scientific foundations of the impact-specific survey research and econometric model-based studies that they use for inputs.

To circumvent lack of data, this study uses site-choice simulations for beach-going and fishing. These simulations use relevant available information, including demand functions, trips information, known closures, and quality reductions.

6.3 METHODS FOR IDENTIFYING RECREATIONAL BENEFITS

Specifying the baseline model depicted in Figure 6-1 requires representing demand for affected sites and their substitutes for each recreational activity. The following nine-step process was applied for each.

1. Characterize demand curve for each activity.
2. Identify sites and origins.
3. Collect site data.
4. Calculate travel costs from all origins to modeled sites.
5. Identify total trips from origins to modeled sites.

6. Identify trips in modeled time periods.
7. Calibrate site demand curves to allocate trips over sites.
8. Simulate “without HAB” conditions.
9. Scale results to reflect visitors from outside shoreline counties.

This process was applied for beach-going and fishing and the following text provides an overview of the process. Sections 6.4 and 6.5 provide specific details and include, in some cases, details from beach-going and fishing for explanatory purposes. They are included in Sections 6.4 and 6.5 by reference only.

Considering Step (1), demand curve equations were transferred from the best available multi-site recreation study. Information transferred is the travel cost parameter that is responsible for the downward slope of the demand curve in Figures 6-1 and 6-2, and site data that are responsible for its location (Figure 6-2). For Step (2), affected sites were identified as those that are in the western basin of Lake Erie; substitute sites are high-pressure sites that recreators from origins are expected to use as substitute sites. Origins are the center of ZIP codes; these are limited to counties around western Lake Erie. As described in the tourism section, a number of trips come from outside these shoreline counties and many of these trips are related to fishing and beach-going. However, it is impractical to consider all potential origins. Effects to these trips are identified by scaling the shoreline county results.

Site data were collected or specified under Step (3). This is related to the model identified in the first step. Identifying HAB-related variables is the most challenging part of the exercise. Ideally, these variables would map into the rating system presented in Section 3 and there would be related parameters that are econometrically estimated. Primary research of this nature was not an objective of this study. Compensating for this missing information requires specifying coefficients that reflect the importance of each HAB rating for each activity.

The travel costs (4) between origins and sites were based on distances derived from the routing software PCMiler. To calculate distances, origination points were defined as the center of the origin ZIP codes and ending points as the latitude and longitude coordinates of modeled sites. These were converted to travel times by dividing by an average speed of 45 mph. Travel costs are the sum of vehicle operation costs and time costs. Vehicle operation costs are distances times $0.52 (per-mile estimate from AAA [2013]). Time costs were calculated based on average income from each origin ZIP code (taken from the census). This number is divided by 2000 to calculate the hourly wage. The result is then multiplied by 1/3. This is a common “opportunity cost of time” adjustment that reflects differences between work and leisure time (Parsons, 2003).

In addressing Step (5), trips from origins to specified sites are based on estimates of total trips, trips per site, and trips by recreator type. This is based on a combination of external information and expert judgment. For example, the U.S. Fish and Wildlife Service estimates that 18.8 percent of Michigan residents (16 and older) fished an average of 17 days in the Great Lakes and 15.9 percent of Ohio residents fished 6 days in the Great Lakes in 2011 (USFWS 2013b, 2013c). Applying these to the relevant populations from census data allows calculating total trips from each origin ZIP code.

Specification of the number of trips overall and to each site is also based on external information. Due to difficulties of including very large geographies and numbers of sites, not all of trips from origins go to sites that are included in the models and not all trips to sites are from included origins. Professional judgment is used to make appropriate adjustments.

Ohio Department of Natural Resources, Ohio Division of Wildlife (2013), Ontario Ministry of Tourism, Culture and Sport (2014), and Thomas and Wills (2013) provided estimates of fishing trips to the western basin of Lake Erie. About 565,000 trips were taken from Ohio, 163,000 from Ontario, and 842,000 trips from Michigan. These estimates sum to 1.57 million trips.

The "anglers and trips per angler" process above indicates that there are about 470,000 trips to the Great Lakes by Ohio residents from western basin shoreline counties. For Michigan, this process produces 338,200 trips from Monroe County and about 4 million trips from Wayne County alone. Excluding the Wayne County estimates, this totals 971,200 trips. Some of the Michigan and Ohio trips would be to Great Lakes sites other than the western basin, which means that trip estimates should be adjusted somewhat downward. Also, Detroit (in Wayne County) is quite different demographically from the rest of Michigan. We judge that average Michigan angling rates do not apply to Wayne County and these are adjusted significantly downward until approximately 800,000 of the 1.57 million western basin trips are from shoreline counties and are included in the fishing model. The remaining trips from outside these counties are accounted for via scaling of effects from modeled trips.

Step (6): Because the effects from HABs happen only during certain times of the year, the recreation site choice models (which are developed on an annual basis) must be converted into the weekly time scales over which the HAB severity values occur (see Section 3.3.1). External information and professional judgment is used to do this. Considering fishing, the Ohio Department of Natural Resources conducts annual creel surveys that estimate boat angler effort on Lake Erie. These surveys indicate that 27 percent of boat-based fishing trips are in July, 15 percent in August, 10 percent in September, and 5 percent in October. After dividing by four to calculate weekly percentages, these are applied to annual trips to identify trips during HAB-affected weeks.

For the last baseline Step (7), trips are distributed to sites on the basis of travel cost and the other identified site characteristics and coefficients. When information is available that indicates site pressure, a demand shifter is introduced to the equations. This allows moving the demand curve to more accurately match pressure in particular areas.

In Step (8), outcomes for 2011 and 2014 are evaluated by developing an identical model in which HAB effects are set to 0. The by-week and county/island HAB severity metrics range from 0 to 1 for 2011 and 2014. Changing these to 0 results in a new (shifted) demand curve and re-distribution of trips. The benefits of HAB reductions for 2011 and 2014 are calculated as the difference in welfare across the two scenarios as described in the text that accompanies Figure 6-2.

After Step (8) is complete, economic benefits for recreators from outside the shoreline counties are calculated. This occurs in Step (9) by scaling results for recreators from outside shoreline counties to those from inside shoreline counties. For example, Step (5) identified 1.57 million western basin fishing trips from external information and specified that 800,000 of these were from shoreline-county residents. Under this specification, total benefits equal 1.57/0.8 times the benefits from shoreline county residents. The uncertainty associated with this extrapolation was not evaluated.

Additional details on the application of this approach for beach recreation and fishing are presented in the following two sections. To avoid repetition, examples from this text are referenced.

6.4 BEACH RECREATION BENEFITS

Economic benefits from reducing HABs at western basin Lake Erie beaches are identified using the process in described in Section 6.3. The first step (1) involves identifying a suitable beach recreation site choice study from which to transfer demand parameters. The study selected is Murray et al. (2001). This study is specific to Lake Erie beach-going; in addition to the travel cost variable, there are variables that relate trip-taking behavior (and welfare) to the average number of advisories a site has per season and average *E. coli* measurements. None of these describe HABs, however, they can be informative. For example, a site with high *E. coli* counts and many closures could be consistent with a moderate HAB effect.

For Step (2) the study area includes beaches along Lake Erie. Table 6-1 lists the beaches in the U.S. counties of the study area. This list includes beaches studied by Weicksel and Lupi (2013). The Michigan and Ohio beaches are listed as compiled by the Michigan Department of Environmental Quality (MDEQ) (2015a, 2015b, 2015c) and the Ohio Department of Health (ODH) (2015).

Table 6-1: Lake Erie Beaches Located in the Study Area

Location	Beach on Lake Erie
Wayne County, MI	Southern Wayne County Border beach
Monroe County, MI	Evans Pier and Public Beach (Luna Pier) Sterling State Park beach
Lucas County, OH	Ashcroft Drive Basin Access Cullen Park Lake Erie Center Basin Access Maumee Bay State Park Metzger Marsh State Wildlife Area
Ottawa County, OH	Camp Perry Beach Park East Harbor State Park Port Clinton City Beach Port Clinton Lakefront Preserve
Sandusky County, OH	No swimming/bathing beach
Erie County, OH	Cedar Point Chaussee Nickel Plate Beach Sherod Park

For Step (3), there are a number of other site variables; however, these were collected as part of the study. Because this information is not available/difficult to collect (e.g. slope, number of zebra mussels). Information that relates HAB severity to behavior is not available. Here, a moderate (i.e. 0.5) HAB effect in a week is defined as being consistent with historical *E. coli* counts that are associated with a high number of closures.

Step (4) consists of calculating travel costs, and was conducted as described in 6.2. Step (5) relates to the identification of trips from shoreline counties to affected (and substitute) sites. As described in 6.2, this process is based on the integration of available pressure data and trip taking information. Our investigation found little in the way of pressure information for western basin Lake Erie beaches. What we did find was highly variable. For example, the Ohio Department of Transportation (ODT) states that 144,000 Ohioans go to the beach annually (ODT 2014). This number is cited with some frequency (ODT 2014); however, even with a large number of trips per person, this appears to be on the low side. Some websites have information about visits to specific sites, but not all are beach visitors. The study used for transfer purposes identifies 1.8 million visits to 15 Ohio beaches; though, not all of these beaches are in the western basin, and not all western basin beaches are in the 15.

Beginning from trip-taking behaviors, shoreline county population information is readily and reliably available from the census. This information indicates there are 2.61 million adults in the study area. A Longwoods' study says 43 percent of Ohioans go to the beach each year with 72 percent of them visiting a Lake Erie beach. As described in the fishing section, Detroit (in Wayne County) is quite different demographically from the rest of Michigan. We judge that the percentage of these residents who go to the beach each year is half of the 43 percent of Ohioans who go to the beach. Applying these results to Ohio and Michigan shoreline counties implies 702,800 residents of these counties visit Lake Erie beaches each year.

If these residents took three trips to the sites on the western basin of Lake Erie included in the analysis, the 702,800 beach-goers would take approximately 2.1 million trips; trip-taking rates are specified so as to produce this number of total trips.

As is the case for Lake Erie beach-going generally, little information is available to assist in understanding how these trips are distributed over the year. However, the factors that tend to underlie beach-going (sunlight, warm water, vacation availability) are well-known. Based on this, step (6) specifies that 28 percent of all trips occur in July (7 percent/week), 20 percent take place in August (5 percent/week), 10 percent are in September (2.5 percent/week) and 4.5 percent in October (1.25 percent/week). This approach results in 1.3 million trips modeled as being taken by shoreline county beach-goers during the HAB-affected months.

Under Step (7), the coefficients from Step (1), the travel costs from Step (4), and the site characteristics from Step (3) were put in a multi-site choice equations where people from origins of Step (2) probabilistically choose sites from Step (2). Then, trips by ZIP Code from Step (6) are multiplied through to produce trips to each site.

Closures were accounted for by introducing demand shifters to set trips. The Ohio EPA (2015) compiles "Algal Toxin Results from Lake Erie, Ohio State Park Beaches, and Public Water Supplies (2011–Present)," which lists the microcystin levels at testing sites throughout Ohio. A Recreational Public Health Advisory is issued when the microcystin level reaches 6 parts per billion (ppb), and a Recreational No Contact Advisory is issued when toxin levels exceed the recommended threshold (20 ppb) and there are one or more probable cases of human illness or pet deaths attributable to HABs. Based on the microcystin levels reported in the "Algal Toxin Results from Lake Erie, Ohio State Park Beaches, and Public Water Supplies," an advisory attributable to HABs was issued for these sites during 2014:

- South Bass Island State Park beach, two weeks from late August through mid-September
- Village of Put-in-Bay beach, two weeks from late August through mid-September
- Maumee Bay State Park beach, at least six weeks from July 23 through Labor Day.

Maumee Bay State Park beach is the only one of the three sites above that is included in the model. Using the closures listed for Maumee State Park beach, Weicksel and Lupi (2013) estimated that 178,500 trips were to this site in 2011. Using an alternative benefit function transfer, Palm-Forster (2015) estimates there are 293,000 trips to this beach, but because this too is based on a transfer, the actual number is unknown. Therefore, a demand shifter is introduced in order to estimate 178,500 trips to Maumee Bay State Park in 2011.

In Step (8), a model is developed where the site characteristics from Step (3) are identical except for the HAB effects. These are set to 0. This allows identifying a new distribution of trips. The benefits of HAB reductions for 2011 and 2014 are calculated as the difference in welfare across the two scenarios as described in the text that accompanies Figure 6-2.

Weicksel and Lupi (2013) used Murray et al.'s results to estimate damages in 2011 for Maumee Bay State Park beach ($1.3 million). The HAB rating coefficient is calibrated so that the model estimates $1.3 million in benefits for Maumee Bay State Park under the 2011 HAB reduction scenario. The effect of this HAB rating calibrator is applied to the remaining sites to estimate the recreational beach benefits.

Reduction of HABs for the 1.3 million trips taken by 702,800 beach-goers during the affected months results in $7.19 million in benefits in the 2011 scenario and $5.61 million in benefits in the 2014 scenario. Scaling to reflect losses by visitors from outside the county is based on the specification that 50 percent of trips are from outside the county. This is supported by Murray et al. and Longwoods, which indicate 20 percent of trips are overnight and reasonably specified as coming from outside the county. Another 30 percent of day trips could come from outside shoreline counties. This has not been validated and beach pressure overall, by type, and by site is noted as a substantial uncertainty worthy of deeper study. Specifying that half of trips are not covered in the modeling leads to total beach impacts for the 2011 scenario of $14.38 million and for 2014 of $11.22 million.

Reduction of HABs for the 1.3 million trips taken by 702,800 beach-goers during the affected months, and noting that half of the trips are not covered in our modeling, results in $14.38 million in benefits in the 2011 scenario and $11.22 million in benefits in the 2014 scenario.

6.5 FISHING BENEFITS

Economic benefits from reducing HABs at western basin Lake Erie fishing sites are identified using the process described in Section 6.3. The first step (1) involves identifying a suitable fishing site choice study from which to transfer demand parameters. The study selected is Melstrom and Lupi (2013). This study is specific to Michigan angling, but is a high-quality study suitable for transfer to Ohio; in addition to the travel-cost variable, there are other variables that relate trip-taking behavior (and welfare) to catch rate. Unfortunately, there are no variables to relate fishing behaviors to site water quality; nor was the team able to characterize links between HABs and catch rates.

Step (2) consists of identifying sites and origins. Origins are again identified as ZIP codes within the shoreline counties. Considering sites, anglers can choose among many, quality fishing sites near the western basin, as shown in Table 6-2. Besides the River Raisin and Lake Erie, the most attractive fishing sites include Lake St. Clair and the Detroit, St. Clair, and Maumee rivers. Along with Lake Erie, Lake St. Clair and the Detroit and St. Clair rivers are nationally-known for the size and number of smallmouth bass that anglers catch (MDNR 2013a).

Table 6-2: Fishing Sites Located in the Study Area

Location	Fishing Site
Wayne County, MI	Lake Erie Belleville Lake Detroit River
Monroe County, MI	Lake Erie (Luna Pier) Huron River River Raisin
Lucas County, OH	Ashcroft Drive Basin Access Cullen Park Lake Erie Center Basin Access Maumee Bay State Park Metzger Marsh State Wildlife Area
Ottawa County, OH	Camp Perry Beach Park East Harbor State Park Port Clinton City Beach Port Clinton Lakefront Preserve
Sandusky County, OH	No swimming/bathing beach
Erie County, OH	Cedar Point Chaussee Nickel Plate Beach Sherod Park

For Step 3, relevant site data is catch rates. For Steps 4, 5, and 6 travel costs, total trips, and trips in modeled time periods were conducted as described in Section 6.3.

For Step 7, totals for Lake Erie were identified as 790,925 for District 1, 490,829 for District 2, and 73,914 for District 3.

Step (8) involves the simulation of "without HAB" conditions. Anglers could avoid sites both because HABs are unpleasant to fish in, and because HABs can have detrimental effects on catch rates. A recent survey of Ohio anglers suggests they are willing to travel to avoid sites affected by HABs (Zhang and Sohngen, 2015). However, because no published studies exist that have evaluated these specific effects, considerable professional judgment is relied upon.

So far as fishing benefits, reduction of HABs are expected to lead to a $10 million benefit for the 2011 event, and $7 million benefit for the 2014 event.

Relevant fishing models tend to focus on catch. Thus, HAB effects are added by expert judgment and also via their effect on catch rates. This latter effect also has scarce information, which underscores the need for biological data that relates HABs to catch rates at the local level. HAB effects are set in total equal to catch effects and then scaled over the 0 to 1 HAB severity ratings, which results in $10 million in estimated benefits for 2011 and $7 million for 2014.

6.6 BOATING BENEFITS

Benefit estimates for recreational boating were noted as being areas for further investigation in Weicksel and Lupi's (2013) report. Direct estimates of boating pressure were not readily available. However, population-level information is. A 2013 survey found that 30 percent of Ohio visitors planning a trip to Lake Erie intended to go boating (Ohio DOT 2014). According to the Ohio DOT, an estimated three million Ohioans go boating each year (23.4 percent of the population). The *Michigan*

Statewide Comprehensive Outdoor Recreation Plan 2013–2017 estimates that 11 percent of Michigan residents participate in boating (Public Sector Consultants Inc. 2012). Certain information is specific by locality. For example, an estimated 16,722 of Monroe County residents go boating each year, along with an estimated 49,826 visitors (Public Sector Consultants Inc. 2012; D.K. Shifflet & Associates, Ltd. 2011). An estimated 200,264 of Wayne County residents go boating each year, along with an estimated 14,080 visitors to the study area (Public Sector Consultants Inc. 2012; D.K. Shifflet & Associates, Ltd. 2011).

For boating, reduction of HABs is expected to result in $10 million in benefits in the 2011 scenario, and $5 million in benefits in the 2014 scenario.

We found no direct boating pressure effort data is available for boating pressure so an estimate was developed based on relationship to fishing trips. Ohio boaters collectively spend half their time on the water fishing. This implies an equal number of boat angling trips and boat trips. Boating pressure is specified consistent with the western basin pressure described in Section 6.3 as 500,000 trips per year with this being a substantial uncertainty. Following the procedure for beach-going, approximately 300,000 of these are modeled as being over the potentially-affected time period. Based on these trips and on transferred results from beach going, with per-trip values being set at twice the value of beach trips these losses are estimated at $7 million for 2011 and $5 million for 2014.

6.7 NEXT STEPS

Recreation is fundamentally important on Lake Erie. The presence of HABs disrupts this activity. There is currently no study in the literature that quantitatively links the presence and severity of HABs with changes in recreation demand. The analysis conducted for this report transfers results from other relationships to parameterize the effect HABs have on beach use, fishing, and boating. A key next step would be to undertake a recreation demand study to quantify the effect that changes in the presence and severity of HABs has on recreational beach use, fishing, and boating demand. The study would also better quantify the baseline level of beach use, fishing, and boating trips to western Lake Erie.

7.0 POTENTIAL IMPLICATIONS OF HABS FOR FARMING, INDUSTRIAL, MUNICIPAL AND PRIVATE WATER WITHDRAWERS

7.1 IMPORTANT DRINKING WATER SERVICES AND THEIR RELATIONSHIP TO HABS

Organizations and individuals withdraw water from Lake Erie for a variety of purposes. These include farming, industrial processes, private household supply, and public water supply. HABs can interrupt these important services, causing welfare losses.

Weicksel and Lupi (2013) did not identify impacts to farming and industrial processes or private wells, but did identify related public water systems (PWS) treatment costs based on results from the Ohio EPA survey of PWS. The 2009 survey, then the most recent data, included responses from 15 PWS drawing water from all basins of Lake Erie. Ten of those reported using additional treatments in response to HAB events in 2009. Respondents reported $417,200 in HAB-related control costs, with a range of $400 to $240,000 per respondent. Treatments included the application of powdered activated carbon, chlorine dioxide, and potassium permanganate.

7.2 FARMING AND INDUSTRIAL USES

HABs could potentially reduce water availability for farming and industrial purposes. Farming includes watering livestock and irrigation. Both of these sectors potentially draw directly from Lake Erie. Considering livestock watering, this investigation found no evidence of significant livestock watering directly from Lake Erie. This effect is not considered further here.

In 1993, the International Joint Commission Working Committee 2, Land Use and Management noted that "only a few farmers used Lake Erie water for irrigation purposes." However, during recent years this has changed somewhat as farmers in southwestern Ontario have adopted drip-irrigation technologies for several crops (Tan and Reynolds 2003).

Leamington Area Drip Irrigation Inc., spent seven years and millions of dollars to construct a 36-kilometer pipeline (about 22 miles) for drip irrigation in their fields. This pipeline has supported irrigation for 2,500 acres of land since 2009. The water from Lake Erie replaces treated drinking water that the farmers previously used.

Ontario has the highest concentration of vegetable greenhouses in Canada, and 78 percent of that greenhouse acreage is in Essex County (IFAJ 2011; Town of Kingsville 2015). Some of the Essex County greenhouses also grow fruit or flowers. Beaulieu (2007) estimated greenhouse water use in Ontario exceeds 22,000 cubic meters annually. Except for the few connected to the Leamington Area Drip Irrigation pipeline, it is unlikely that water used in Essex County greenhouses is drawn directly from Lake Erie. Regarding benefits from HAB reductions, potential scenarios include returning to the use of municipal water, switching to less water intensive crops, or conducting additional water filtering.

The first outcome would imply Leamington Area Drip Irrigation members at least temporarily return to municipal water for irrigating crops. The system supports up to 7,000 gallons (26,498 liters) per minute, but a permit limits the total volume of water that can be withdrawn from Lake Erie (Hill 2011; AgMedia, Inc. 2010). Coolong (undated) estimates peak water use for tomatoes (the most valuable crop) would require using 20,555 to 30,836 liters (5,430 to 8,146 gallons) per acre per day.

Farmers could use less water to grow lower valued wheat, soybeans, or corn (Wells 2014; Davidson 2013). This may already be occurring;

however, it is not a result of HABs. The H.J. Heinz Company recently sold its Leamington catsup factory to Highbury Canco Corporation. The Highbury operation will employ fewer people and will process tomato juice and other foods, but not catsup. As of June 27, 2014, only ten of 46 farmers in Essex and Kent Counties have tomato contracts with Highbury Canco (Wells 2014; Davidson 2013).

There is no available evidence indicating that reducing Lake Erie irrigation usage either by switching to municipal water or by growing less or different crops has occurred as a result of Lake Erie HABs. There is anecdotal evidence (IJC meeting) that algae has clogged the Leamington Area Drip Irrigation system and led to increased filtering and cleaning costs. However, this organization does not have public contact information, the magnitude of these costs is unknown, and it is not certain these issues were caused by HABs.

Industrial water users could be affected as facilities use Lake Erie water for food or beverage purposes would incur filtering and treatment costs These would be facilities that have their own water treatment plants rather than using municipal water. For example, a large beer brewery might find it cost effective to treat its own water. This study included extensive searching for non-PWS intakes drawing water from western Lake Erie for food or beverage purposes but did not find any. For this reason, we expect the cost of providing HAB-free water to these facilities is borne by the public water systems.

Power plants are the primary facilities using water for cooling purposes. The Fermi, Monroe, Whiting, Bay Shore, Davis Besse, West Lorain, and Avon Lake power plants all draw cooling water from the western basin and could be affected. For cooling purposes, the water would likely not require additional treatment. Filtering is accomplished at these plants using screening systems. Although there is anecdotal evidence that at least one of these plants has experienced additional algae-related filtering costs, the costs and nature of the algae (HAB or not) is unknown. No public information indicates these facilities have incurred additional costs.

Although this review indicates the potential for effects to farming and industrial uses from HABs and their reduction, no evidence of significant costs for the period covering 2011 to 2014 was identified. Accordingly, although there may have been benefits of reducing HABs in 2011 and 2014, these benefits are not identified and have been quantified as zero. This extends to the evaluation of lagged effects, which is also quantified at zero.

7.3 MUNICIPAL AND PRIVATE USES

Lake Erie and its tributaries supply water for household and business uses to 13 million people in Ontario and states bordering the three basins (Ohio Environmental Council 2014). This water is supplied both by municipal water supplier and wells.

7.3.1 Effects to PWS

In the western basin of Lake Erie, at least 18 water treatment plants draw water directly from the lake: four from Essex County, Ontario; 12 from Ohio; and two from Michigan (which share an intake) (Essex Region Source Protection Area 2015; Michigan Department of Environmental Quality 2014; Ohio Environmental Protection Agency [EPA] 2013).

Post-2009, public water suppliers were still adjusting to HABs. During early August 2014, wind and water currents pushed the HAB from Lake Erie's western basin to the area where Toledo, Ohio's Collins Park Water Treatment Plant takes in water from the lake. Wind and waves mixed the cyanobacteria into the water column, and they were sucked into the water plant.

On August 2, 2014, the treated drinking water exceeded the 1 ppb threshold for safe drinking water recommended by the World Health Organization and adopted by the Ohio EPA. The City of Toledo issued a drinking water ban until the morning of August 6. Nearly one-half million people were affected. In addition, Toledo Mayor D. Michael Collins strongly recommended all restaurants close operations during the ban (Dierkes 2014; Dolan 2014; Sonich-Mullin 2014).

7.3.2 PWS Adaptation Costs

The cyanobacterium microcystis found in Lake Erie HABs can be removed from drinking water drawn from the lake. However, removing microcystis increases the cost of water treatment by $3,000 or more per day (Dierkes, 2013). Water-treatment plants also incur expenses for water testing. Raymond (2014) stated that "many Lake Erie water systems routinely add carbon to address HABs," with Toledo spending as much as "$200,000/month on carbon." Carroll Township "upgraded $125,000 ozone treatment in response to finished water microcystin detections."

Toledo, Oregon, Carroll Township, Ottawa County, Sandusky, Kelleys Island, and Camp Patmos public water systems responded to a 2014 survey conducted by the Ohio EPA. The survey gathered data about expenses related to algae monitoring and mitigation. Table 7-1 summarizes the expenses reported by the survey respondents in these categories:

- Water monitoring
- Equipment and training
- Annual source water algae control (e.g., algaecide, alum, oxidants, and other reservoir or source water treatments)
- Treatment options (such as PAC, GAC, ozone, increased chemical costs, increased electricity expenses, and increased staff time) for reducing algae-related issues like taste and odor compounds, cyanotoxins, or disinfection byproducts (DBPs)
- Maximum monthly expenses related to algae monitoring and mitigation
- Capital costs for advanced treatment used to reduce algae-related issues (PAC feed, GAC towers, ozone system, UV and membrane filtration).

The totals in Table 7-1 reflect totaled annual expenditures.

Table 7-1: Expenses of Monitoring and Mitigating HABs Reported by PWS in Ohio

Number of PWS	Expense Category	Reported Expenses
Five	Water monitoring	$233,000
Four	Equipment and training	$110,750
Three	Source water algae control	$308,800
Six	Treatment options for reducing algae-related issues	$2,028,353

These total $2,680,903 in annual HAB-related treatment costs. Moreover, four respondents incurred a total of $515,000 in capital costs.

7.3.3 Private Well Effects

Well water contaminated with HAB toxins is not available for household uses. On August 26, 2014, the Lake Erie HAB thickened around Pelee Island. Some private wells showed levels of microcystis above the safe level for drinking water. As a result, the Health Unit warned approximately 500 Pelee Island well owners to drink only bottled water or to pick up water from a tanker at the municipal treatment plant. Fifteen days later on September 9, the ban on using well water was changed to an advisory (CTV Windsor 2014; McCray and Henry 2014; *Toledo Blade* 2014; Yeager-Kozacek 2014).

Although other private wells exist near Lake Erie, the investigation did not uncover evidence of these being affected. There is an important reason for this. Whereas mainland wells draw from aquifers that are not connected to Lake Erie, most of the approximately 500 homes on Pelee Island, Ontario, use private, shoreline wells which draw water from Lake Erie (McCray and Henry 2014).

7.4 BENEFITS OF REDUCING FUTURE HABS

The characterization of the benefits of reducing future HABs for this study asks the question "what is the economic benefit of eliminating future HABs that are like the 2011 and 2014 HABs?" It also asks the related question "what is the lagged (i.e., intertemporal) benefit of eliminating future HABs?" These questions are useful in that they are forward-looking and policy-relevant; they also have important implications for what is categorized as a benefit.

In particular, much of the expenditures in Table 7-1 are from the Toledo public water system. The Toledo event was a dramatic interruption of water services and had severe implications for economic welfare for households and businesses. These impacts are being studied elsewhere. Also, these expenditures were undertaken to ensure the water interruptions of 2014 would not recur. As a result, this study presumes that a future HAB like the 2014 HAB would not result in water supply interruptions in Toledo and the significant welfare losses that accompanied that event. In contrast, there is no evidence that mitigating measures have been undertaken on Pelee Island; an event like 2014 occurring in the future would presumably have effects similar to those that occurred in 2014. The implications of this context are that for service interruptions there are no human welfare-related benefits identified for the 2011 scenario and the human welfare-related benefits for 2014 are those associated with the Pelee Island water supply disruption.

Regarding the 500 well users who were affected by the “do not use” order for Pelee Island, to avert the lack of well water, users may have purchased bottled water, procured water from a tanker at the municipal water plant, or moved temporarily to mainland Essex County or another area, living with friends or relatives or renting temporary accommodations.

Pelee Island businesses relying on well water (such as greenhouses) may also have been affected by the “do not use” order, but it is unclear how many were affected. Detailed information about the scope of inconvenience experienced on Pelee Island is not available. For purposes of this assessment, we consider that not being able to use household water is best offset by temporarily relocating. If 500 families spent $100 per night for 15 nights in alternative accommodations, this averting expenditure would total $750,000.

Considering lagged effects to welfare, given the relatively obvious nature of the HABs, and responsibility of public health authorities for providing appropriate information, we do not anticipate significant lagged or halo effects where, for example, people in areas that have experienced HAB impacts to their water supply no longer use municipal/well water. This effect is certainly possible and was mentioned anecdotally (IJC meeting), however, we have found no evidence of persistent effects.

Regarding averting costs, of at least 18 western basin plants, HAB-averting costs are only available for six. As the survey only covered Ohio, this leaves six other plants from Ohio that did not report costs, as well as four from Essex County and two from Monroe County. Whether or not these plants are incurring treatment costs is unknown. With the exception of Toledo, which incurred most of the costs, and in response to the 2014 HAB, it is not known whether these are in response to a particular event.

An additional, important consideration is that the investment and ongoing annual expenditures for HAB-related water treatment will be conducted regardless of whether a HAB like that of 2011 or 2014 occurs. Because these expenditures do not depend on HABs, reducing them will have no immediate benefit in terms of treatment cost reductions. This means there is no clear benefit related to water treatment costs associated with the 2011 and 2014 scenarios for the Ohio water treatment plants that responded to the survey.

Consequently, these costs appear under the lagged effects scenario. Given the available information, Ohio PWS are incurring $2,680,903 annually because of past and anticipated future HABs. Moreover, four respondents incurred a total of $515,000 in capital costs and information is unreported for six potentially-affected Ohio facilities and unavailable for two facilities in Michigan and two facilities in Essex County. Extrapolating to other facilities is difficult because one PWS in Toledo that experienced dramatic impacts comprises most of these costs. However, costs of approximately $3 million are estimated.

7.5 SUMMARY AND NEXT STEPS

Organizations and individuals withdraw water from Lake Erie for a variety of purposes that can be affected by HABs and cause economic damages. While impacts of HABs on public and private water supply were well-publicized, the review in Section 7 identified scant evidence of much impact on direct water users, such as agricultural and industrial production. Although there is anecdotal evidence of increased filtering for some agricultural uses and for some power production, the review of evidence does not suggest this service warrants further research. However, this conclusion could change if new, large water users, such as food and beverage processors, were to require water drawn outside of the public water supply.

The review did identify data on averting costs for public water suppliers. A recent survey of public water suppliers in Ohio indicates increased treatment costs for HABs, suggesting averting costs of approximately $3 million per year are being incurred. These expenditures are ensuring water supply is available, even with severe HAB events. If these current expenditures, in part in response to the 2014 HAB event, ensure no future disruption of the public water supply from HABs, then there are no additional economic damages that would be further caused by service interruptions. However, the Toledo service interruption caused well-publicized business closures and impacts on households. In addition, some individuals still do not use the public water supply out of concerns for water safety. If current averting and treatment costs do not adequately protect against HAB interruptions to potable water supply or do not change individuals behavior, further documentation on and research into losses of such events is highly warranted.

The impacts of past HABs have also affected private well users. For example, at Pelee Island well water is taken from Lake Erie; data was sparse as to the exact nature of the economic damages the 2014 event imposed on Pelee Island residents, but coarse assumptions suggest it was in the range of $750,000. Much better information could be assembled for this case by doing primary research and data collection about residents' response to the 2014 event. A key next step would therefore involve gathering behavior-specific and cost data on what residents of Pelee Island did to mitigate the 2014 HAB, how much they spent on their mitigation efforts, and identify whether they have made any capital investments or behavioral changes to avoid having to undertake those mitigation activities under future HAB events.

Longer-term, it is unknown if any changes have occurred in how households use publically-supplied or private water in response to HAB events. For example, households may switch to filtered or bottled water for some uses. Understanding how households responded to the HAB events of 2011 and 2014 would require more in-depth analyses and likely benefit from primary data collection, such as a household survey, which, in turn, would be able to identify any persisting and as yet unquantified economic losses for HABs due to potable water supply.

8.0 NEXT STEPS

The analysis presented throughout this report has relied on available secondary data and studies to quantify the economic benefits of HAB reductions. The reliance on secondary data and studies results from the fact that little primary data has been collected and few studies conducted to quantify the economic benefits of HAB reductions in the scientific sense of identifying statistically-significant parameters within rigorous econometric methods. However, the analysis presented in this report has identified what the construct of these econometric models might be, what the data needed to populate them might include, and which specific parameters would be most useful to more-accurately quantify the economic benefits of HAB reductions. Next steps are provided below.

8.1 PROPERTY VALUES

There is no specific study in the literature that identifies the number of properties with value at risk from the presence and severity of HABs, nor are there any studies that scientifically examine the relationship between the presence and severity of HABs and the amount of property value losses. The research presented in sections 3 and 4 only begins to quantify the presence and severity of HABs, and identify the amount of properties that have value at risk. A recommended next step would be to develop an econometric model to link data on the presence and severity of HABs, as identified in Section 3, with sales and owner-preference data to evaluate HABs and property value losses. Such a study would replace the transfer and scenario-based evaluations conducted for this analysis with a parametrized evaluation of the property value effects of HABs.

For example, Section 4 examined the potential for HABs to damage property values, focusing on residential properties on or near the shoreline. Using multiple methods, it was demonstrated that there are likely over $3 billion worth of residential properties that are at risk of damages from HABs. How much value is then at risk depends on the intricacies of the link between property values and HABs. The available literature on how low water quality and how disasters impact property values provides ample and repeated support that such events impact property values. However, no single existing study provides a close enough match to HABs on Lake Erie to serve as a completely suitable source for benefits transfer.

A review of the literature suggests that low water quality can have long-term impacts on property values and disasters can substantially affect property values for time periods around a disaster. Whether the effects of HABs, which differ in their impact every year, are short term or longer term is an important open question that warrants future study. Taking some values from the literature on the percentage impact that environmental harms can have on property values serves to illustrate the magnitude that damages from Lake Erie HABs might be: a 5 percent impact to near-shore values and a 10 percent impact to shoreline properties results in $242.1 million in property value impacts. To give another perspective, another approach was taken to illustrate potential residential property losses due to HABs. By considering when and where residential property services such as views are impaired by HABs and using the spatial and temporal scenarios described in Section 3 for the 2011 and 2014 HAB events, and making some exploratory assumptions about the temporal pattern of housing service flows, per event losses are on the order of $17 million. Clearly the range of impacts remains uncertain. Future work could involve a more detailed study that accesses tax assessor data and more fully describes all the property values along the shore and in the nearshore areas where HABs are a risk. Similarly, commercially available, but costly, data exists on housing sales that is suitable for identifying the relationship of sale prices to HAB events, HAB risks, and proximity to HABs. A related line of research could also incorporate homeowner preference data from surveys. Since shoreline and nearshore property owners are important stakeholders, a viable option for addressing the impacts of HABs on property values is to combine survey-based research approaches with formal property value models, as was done for contaminated sediment remediation in Waukegan Harbor (Braden et al, 2004).

In the current effort, although less-time consuming and coarser methods were used, this study was able to clearly demonstrate the substantial value of the housing stock at potential risk of damage from HABs. Coupled with the published evidence that environmental harms affect property values in a variety of similar cases, it is also clear that property is damaged by HABs and their expected occurrence. The substantial potential for damages makes this a key area for future study.

8.2 TOURISM

HABs can potentially affect the closely-related areas of tourism, business profitability, and commercial property values in areas close to western Lake Erie, which can directly translate into lost income and profits and constitute a potentially large economic damage associated with HABs. Section 5 showed that counties adjacent to western Lake Erie experience millions of out of town trips and billions of dollars in tourism expenditures annually. Although not all of this is directly related to Lake Erie, and only a portion occurs during HAB-affected time periods, it is clear that significant tourism revenue is at risk due to HABs. A portion of this revenue is profits. Not losing these profits would constitute a direct benefit, which would also be reflected in the value of businesses and commercial property. Section 5 reported on efforts to make some assumptions and use existing, readily-available data to assess these economic losses. However, it was noted that very little specific and useful data is available and more thorough research is recommended.

There are numerous parameters relating the presence and severity of HABs to changes in tourist activity that are not well understood and that were specified as defined scenarios for this analysis. A key next step would be to develop scientifically-based evaluations of the following:

- The relationship between the percent of total late summer and early trips to counties that border western Lake Erie and those trips that are related to Lake Erie.
- Develop a scientific evaluation of the relationship between the presence of HABs and diverted tourist trips.
- The relationship between the types of trips that are diverted because of the severity of HABs, where those trips are diverted to, and the amount of spending on those diverted trips.

Despite these limitations, Section 5 illustrated that tourist dollars in Ohio at risk from HABs range from $66 million to $305 million. Associated high-end lost profits are $21 million but could be under $1 million. In Michigan, about $25 million in tourism economic impact was judged to be at risk, which was associated with lost profits of $1.7 million on the high end. For Canada, impacts at risk were about $17 million with high and low-profitability impacts ranging from $1.6 million to $59,000. Again, deriving these numbers from readily available data require numerous assumptions, and given the large ranges of uncertainty warrant further refinement. Moreover, these rough estimates apply only for years with significant blooms including 2011 and 2014. Considering lagged effects, these would occur as tourists forgo trips in years with lesser blooms and are expected to be lower, but there is currently no available data to quantify these.

8.3 RECREATION

There is currently no study in the literature that fully links the presence and severity of HABs with changes in recreation demand. The analysis conducted for this report transfers results from other relationships to parameterize the effect that HABs have on beach use, fishing, and boating. A key next step would be to undertake a recreation demand study that would quantify the effect that changes in the presence and severity of HABs has on recreational beach use, fishing, and boating demand. The study would also better quantify the baseline level of beach use, fishing, and boating trips to Western Lake Erie. Beach use and boating for reasons other than fishing are noted as being especially lacking in spatial and temporal data on trips.

8.4 FARMING, INDUSTRIAL, MUNICIPAL, AND PRIVATE WATER WITHDRAWERS

Organizations and individuals withdraw water from Lake Erie for a variety of purposes that can be affected by HABs and cause economic damages. While impacts of HABs on public and private water supply were well-publicized, the review in Section 7 identified scant evidence of much impact on direct water users such as agricultural and industrial production. Although there is anecdotal evidence of increased filtering for some agricultural uses and for some power production, the review of evidence does not suggest this service warrants further research. However, this conclusion could change if new, large water users such as food and beverage processors were to require water drawn outside of the public water supply.

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The impacts of past HABs have also affected private well users. For example, at Pelee Island well water is taken from Lake Erie; data was sparse as to the exact nature of the economic damages the 2014 event imposed on Pelee Island residents, but coarse assumptions suggest it was in the range of $750,000. Much better information could be assembled for this case by doing primary research and data collection about residents' response to the 2014 event. A key next step would therefore involve gathering behavior-specific and cost data on what residents of Pelee Island did to mitigate the 2014 HAB, how much they spent on their mitigation efforts, and identify whether they have made any capital investments or behavioral changes to avoid having to undertake those mitigation activities under future HAB events.

Longer-term, it is unknown if any changes have occurred in how households use publically supplied or private water in response to HAB events. For example, households may switch to filtered or bottled water for some uses. Understanding how households responded to the HAB events of 2011 and 2014 would require more in-depth analyses and likely benefit from primary data collection, such as a household survey, which in turn would be able to identify any persisting and as yet unquantified economic losses for HABs due to potable water supply.

8.5 OTHER VALUES

The presence of HABs and the resulting changes in environmental quality are expected to affect a range individuals who value the aesthetics of Lake Erie without HABs. These include some values that accrue to individuals who do not partake in water-based recreation or coastal tourism, as well as those who do not own waterfront property. In that way, these can be thought of as non-consumptive values: the values are simply for the existence of the resource in a desirable state. Should HABs continue or worsen, these non-consumptive values would diminish as well. Researchers can apply survey-based, stated preference valuation to estimate such values and economic values of this type have been documented in other settings involving water quality (Johnston et al. 2003; Viscusi et al. 2008). Such non-use values for those who prefer Lake Erie to have less HABs could exist across a broad swath of the Lake Erie region encompassing a large population, hinting that modest values could translate to large benefits for HAB reduction.

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