

The Great Lakes Ecological and Economic Protection Act of 2015

An Environmental and Scientific Assessment





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The Great Lakes Ecological and Economic Protection Act of 2015: An Environmental and Scientific Assessment

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Executive Summary

As the largest reservoir of surface freshwater in North America, the five Great Lakes provide an enormous amount of economic, recreational, cultural and ecological services to 43 million people in the U.S. and Canada (Krantzberg et al., 2006). Due to decades of intense industrial, agricultural and urban development, however, ecological integrity of the Lakes has diminished, threatening both human and wildlife health. Environmental degradation persists as a consequence of nutrient runoff, toxic contamination, invasive species and habitat destruction.

The economic costs and public health risks associated with such environmental hazards are extensive, with annual monetary losses in the hundreds of millions due to aquatic invasive species alone (Rothlisberger et al., 2012). Other costs that burden state and local governments, municipalities, residents and visitors include loss of clean drinking water sources and reduced opportunities for fishing and transportation services. These threats in aggregate could total in the billions of dollars each year, particularly if diminished environmental conditions continue or worsen (Krantzberg et al., 2006).

This report presents an analysis of the scientific problems facing the Great Lakes region and the solutions proposed by the Great Lakes Ecological and Economic Protection Act of 2015 (hereafter, “the Act”), an introduced but not yet enacted bill in the United States Congress.

The Act is meant to provide a robust framework for the funding and continuation of the Great Lakes Restoration Initiative (hereafter, “the Initiative”). Phase I of this Initiative was in place from 2010 to 2014. The proposed Phase II would fund the program through 2019. The Initiative strives to restore the health of the Great Lakes through a variety of projects led by different federal, state, local and tribal government agencies working in partnership with nonprofits, communities, academic institutions and other stakeholder organizations. These projects have produced significant improvements in the region’s ecological health during Phase I of the Initiative. Phase II seeks to build upon these evidence-based successes.

The Act provides the U.S. Environmental Protection Agency (EPA) with extended authority to manage comprehensive restoration efforts, authorizes an annual budget of \$475M for project implementation and completion, and enhances coordination between all responsible government agencies (U.S. Senate, 2015). The Act was introduced by Senator Tammy Baldwin in February 2015 and was referred to the Senate Committee on Environment and Public Works. The bill has 10 cosponsors, including bipartisan support.

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Overview and Background

The Great Lakes consist of five interconnected lakes comprising the world's largest surface freshwater reservoir. The Great Lakes basin lies between the U.S. and Canada, bordering Minnesota, Wisconsin, Michigan, Ohio, Illinois, Indiana, New York, and Pennsylvania in the U.S., as well as the Province of Ontario in Canada. Located near several large metropolitan areas, nearly 30 million people inhabit the Great Lakes Basin, accounting for 10% of the U.S. population and 30% of the Canadian population (EPA, 2012, Great Lakes: Basic Information). The Great Lakes provide a variety of goods and services, including food, drinking water, recreation and transportation. Over the years, extensive logging, industrialization, urbanization, toxic pollution, and agriculture have degraded the Great Lakes' ecosystem (Great Lakes Interagency Task Force, 2005).

Due to this wide range of intensive uses, both historical and contemporary, the Great Lakes have been subject to extensive environmental damage, threatening human and ecological health and the economic prosperity of the region. These environmental ills must be addressed so that the Lakes may continue to serve as a productive local, state and international resource for current and future generations.

The Great Lakes Ecological and Economic Protection Act of 2015 seeks to address past and current environmental harm by amending the Federal Water Pollution Control Act of 1948, commonly known as the Clean Water Act. Through these amendments, the Act would authorize five additional years of funding for the Great Lakes Restoration Initiative, which was created in 2010 by the Obama Administration and is responsible for leading efforts to improve the ecological integrity of the Great Lakes region. Phase I of the Initiative (2010-2014) spent over \$1.6 billion in efforts to restore and maintain the Great Lakes (Great Lakes Restoration Initiative, 2014, Action Plan II). The Initiative fosters collaboration between federal, state, and local government agencies, among other stakeholder organizations, to address the most serious threats to environmental health and quality of life in the Great Lakes region.

Legislative Summary

The Act outlines modifications to the Clean Water Act, specifically to the Great Lakes Water Quality Agreement of 1972 and its amendment, the Water Quality Agreement of 1987, whereby the U.S. and Canada formerly acknowledged a need to protect the Great Lakes region from further degradation. The Great Lakes Ecological and Economic Protection Act of 2015 primarily seeks to:

- 1) Reauthorize the Great Lakes Restoration Initiative for five years and allocate \$475 million in annual funding;
- 2) Permanently establish the Great Lakes Advisory Board to provide advice and recommendations on matters pertaining to restoration and protection;
- 3) Permanently establish the Great Lakes Interagency Task Force to increase coordination among federal agencies and non-federal stakeholders; and
- 4) Implement a requirement for annual comprehensive restoration and crosscut budget reports

1. The Great Lakes Restoration Initiative

Launched in 2010, the Great Lakes Restoration Initiative provides a framework for achieving long-term goals of protecting and restoring the world's largest surface freshwater system (Great Lakes Interagency Task Force, 2014). The Initiative's aims include cleaning up Areas of Concern, which are geographic areas that have suffered significant environmental contamination due to human activities; preventing and controlling invasive species; reducing nutrient runoff contributing to harmful algal blooms; adapting to climate change; and restoring habitat to protect native species (Great Lakes Interagency Task Force, 2014). The Act would reauthorize the Great Lakes Restoration Initiative to evaluate, identify, implement, and fund proposals addressing key environmental problems facing the Great Lakes through 2019 with a \$475 million annual budget.

2. The Great Lakes Advisory Board

The Act would permanently establish a Great Lakes Advisory Board to provide advice and recommendations on matters pertaining to Great Lakes restoration and protection. The Board was originally established in 2012 under a two-year charter in accordance with the provisions of the Federal Advisory Committee Act. The Act would permanently reauthorize the Board's mandate and expand membership from 15 members to include up to 20 members, who will be appointed by the U.S. Environmental Protection Agency (EPA) Administrator. Represented stakeholders will include state, local and tribal governments, environmental and conservation organizations, hunting and agricultural interests, academia, the business sector, and others. The Board will convene at least once every six months in an open-to-the-public setting (EPA, 2012, Great Lakes: Basic Information).

3. The Great Lakes Interagency Task Force

The U.S. and Canada acknowledged environmental damages to this region and the need to take action through the Great Lakes Water Quality Agreement, first signed in 1972 (EPA, 2015, Great Lakes Water Quality Agreement, 2015). Since then, the U.S. has implemented a series of policies to rehabilitate the region, most recently the Great Lakes Restoration Initiative. The Interagency Task Force was created by Executive Order in 2004 during the Bush administration (U.S. Government Publishing Office, 2004). The Great Lakes Ecological and Economic Protection Act would permanently establish the Task Force under law. The Task Force is a cross-governmental body comprised of representatives from 10 federal Departments and Agencies, chaired by the EPA. The Task Force's mission is to promote collaboration and coordination of the Great Lakes Restoration Initiative. More specifically, it is assigned to: (1) collaborate with Canada; (2) coordinate the development of federal policy strategies and projects; (3) set priorities for addressing Great Lakes restoration and protection; (4) assist with Great Lakes system management; (5) develop outcome-based goals for the Great Lakes system while relying on science-based indicators; and (6) review, update, and revise the Restoration Initiative Action Plan every five years.

4. Accountability

The Act also proposes new mechanisms for reporting to Congress - an annual comprehensive report from the EPA and a crosscut budget report of all funds allocated to the restoration efforts by every agency. The Act sets requirements that enhance the accountability of entities involved in the Great Lakes Restoration Initiative. Under the Act, the EPA is required to submit a comprehensive annual report on the overall health of the Great Lakes to Congress, highlighting the achievements of the past fiscal year, the amounts spent on water quality initiatives, description of surveillance systems, and anticipated successes and costs for the upcoming fiscal year. Additionally, the governors of bordering states and the Interagency Task Force are required to submit a publicly available financial report describing budget proposals, identifying adjustments, and listing projects to be undertaken in the next year.

Environmental Problems, Proposed Solutions, and Measures of Success

Understanding the science behind four central environmental problems is essential to implementing policy and programs needed to improve the Great Lakes ecosystem. These four central problems are:

- 1) Pollution from toxic substances affecting water quality
- 2) Nutrient pollution leading to algal blooms
- 3) Degradation of native habitats and loss of native species
- 4) Negative impacts from invasive species

To address these issues facing the Great Lakes, the Act would fund implementation, management, monitoring and evaluation of restoration initiatives. If approved, the Act would enable continued funding of Phase I programs and of new and additional projects aimed at restoring the chemical, physical and biological integrity of the Great Lakes basin ecosystem (Figure 1). The Act would also support research on emerging contaminants and their impacts on fish and wildlife, economic and recreational activities. Funds could also be used to prevent damages from new invasive species. Key solution areas proposed by the Act include:

- 1) Cleanup of contaminated areas and control of toxic substances
- 2) Reduction of nutrient runoff that contributes to harmful algal blooms
- 3) Restoration of natural habitats to protect native species
- 4) Prevention and control of invasive species

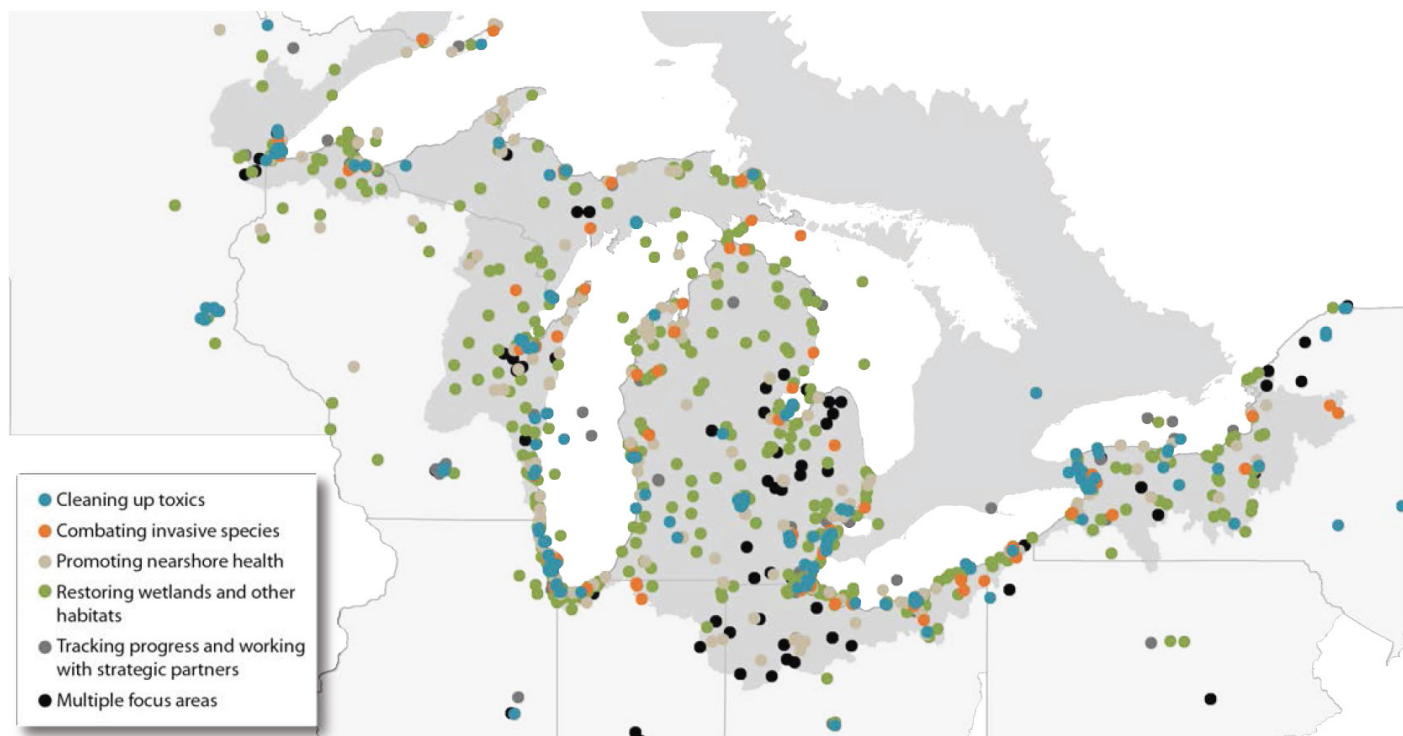


Figure 1. Great Lakes Restoration Initiative projects funded during 2010 - 2013. Source: Great Lakes Restoration Initiative

Over time, these actions should contribute to the long-term environmental and public health improvement goals outlined by the Great Lakes Restoration Initiative and the U.S.-Canada Great Lakes Water Quality Agreement (Great Lakes Interagency Task Force, 2014). The ultimate aim is to achieve permanent improvements in the focus areas outlined above (e.g., all contaminated areas fully recovered and safe for human use, and natural habitats protected and restored).

The Great Lakes Restoration Initiative's Action Plan II outlines the actions intended for Phase II of restoration that would be funded from 2015 to 2019 under the proposed Act (Great Lakes Interagency Task Force, 2014). The Action Plan highlights a science-based adaptive management framework that prioritizes project funding to address the most critical ecosystem problems and to measure outcomes and overall effectiveness.

During Phase I of the Initiative, managers developed a set of measurements for tracking and evaluating the success of the programs. These indicators incorporate a science-based management approach to prioritize problems, select specific projects to address these problems, and to assess project effectiveness (Great Lakes Restoration Initiative, 2014, Action Plan II). Long-term goals include fish and water safe for human consumption, decontaminated areas, controlled populations of invasive species, and restored habitats (Great Lakes Restoration Initiative, 2014, Action Plan II). To achieve these overarching goals, the Initiative provides 24 measures of progress focused on incremental, measurable outcomes to be tracked and achieved by 2019.

Pollution from Toxic Substances Affecting Water Quality

The Great Lakes, which contain 95% of the United States' freshwater reserves and approximately one-fifth of the world's fresh surface water, are increasingly affected by anthropogenic pollution (Great Lakes Interagency Task Force, 2010). One of the severe problems of the Great Lakes region is the presence of numerous high-risk, toxic contaminants. Over 2,000 miles of Great Lakes shoreline, 20% of the total, suffer from some kind of restriction due to sediment contamination (EPA, 2015, Atmospheric Deposition).

PCBs (polychlorinated biphenyl), dioxins, and mercury are present in all five Great Lakes (Figure 2). PCBs are manmade chemicals that were used in electrical equipment from 1929 to 1979 (EPA, 2015, Persistent Organic Pollutants). Dioxins are a group of compounds discharged by industrial waste processes. Their release has been limited through regulation of industrial activities, but significant contamination persists from earlier discharges (EPA, 2011, Dioxins). Other contaminants include toxaphene, chlordane, and mirex, which were formerly used as pesticides (EPA, 2015, Persistent Organic Pollutants). Contamination from pharmaceuticals (e.g. steroids, hormones) is a growing concern too because their environmental accumulation and ecosystem impacts are not monitored or regulated, many are not removed at wastewater treatment plants, and they do not naturally break down quickly.

Due to bioaccumulation and biomagnification, a variety of contaminants may become incorporated into food webs such that small organisms like plankton are not severely affected, but large fish, mammals, and birds are threatened. For plankton in the Great Lakes, PCB concentration is approximately 0.025 ppm. In Lake Trout, it can reach 5 ppm, an increase in chemical concentration of 200 times (EPA, 2012, Great Lakes Monitoring). This example demonstrates how bioaccumulation, which occurs when toxic substances become concentrated within an organism over time, can cause developmental, neurological, or cancerous harm to the organism itself as well

as any creature that consumes it and becomes exposed to the noxious chemical load (EPA, 2014, Understanding PCB Risks).

Biomagnification occurs when toxins present in the lowest levels of the food web (e.g. the plankton) increase in concentration through successively higher trophic levels, heightening health risks to both humans and certain wildlife (EPA, 2015, Persistent Organic Pollutants). For example, human mercury exposure occurs through contaminated fish consumption. Since mercury becomes concentrated in the muscles of fish, it cannot be avoided by cutting off the skin or fat of the fish, as can be done to avoid consuming some other harmful toxins such as PCBs and dioxins (Krabbenhoft, 2013). There are many adverse effects caused by mercury exposure, including damage to the brain and nervous system (Krabbenhoft, 2013).

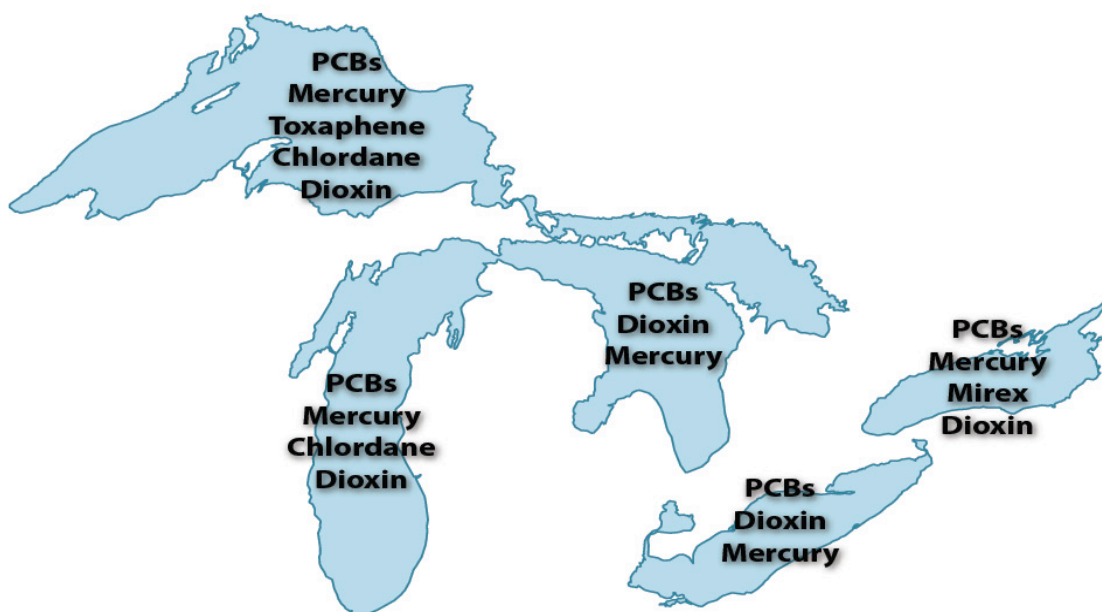


Figure 2. Contaminants in the Great Lakes covered by fish consumption advisories. Chemicals listed are persistent pollutants that pose a continued threat to human and wildlife health. Source: Great Lakes Restoration Initiative.

Human exposure is a continuing public health concern in the Great Lakes and fish consumption advisories are frequently issued for priority contaminants, including mercury, dioxin, polychlorinated biphenyl (PCB), mirex, chlordane and toxaphene (Great Lakes Interagency Task Force, 2014). Exposure to PCBs can cause skin irritation, rashes, and liver damage; PCBs, mercury, and chlordane all impact the human nervous system (EPA, 2012, “Great Lakes Fish Consumption Advisories”). Fish consumption advisories vary by body of water, area of water, and fish species and size; as of February 2015, there were nine locations in Ohio alone where “Do Not Eat” advisories had been issued for sport fish (Ohio EPA, 2015).

Mercury is a heavy metal released when coal is burned for fuel (EPA, 2014, Mercury). While mercury levels have been decreasing in since the 1970’s, some studies suggest that concentration levels have plateaued or even increased slightly in certain fish species within the Great Lakes in recent years (Bhavsar et. al., 2010). This is most troubling because about 11 million people, of whom 2.5 million are children, catch fish in the Great Lakes annually, according to 2006 estimates (NRDC, Poisoning the Great Lakes, 2012). Some of these individuals depend upon the Great Lakes for sustenance and employment, others for recreation (NRDC, Poisoning the Great Lakes, 2012).

Mercury exposure is particularly harmful to infants, children, and expectant and nursing mothers; a 2011 study of babies born in the Lake Superior basin found that 8% of infants had blood mercury levels above the EPA reference dose for methylmercury, meaning that these infants were above the safe threshold after which harmful effects, such as neuropsychological development, might be expected to occur (Great Lakes National Program Office, 2011).

Endocrine disruption is another major human health issue caused by bioaccumulation of contaminants such as dissolved pharmaceuticals in Great Lakes drinking water (Figure 3). The endocrine system is responsible for regulating functions such as cell growth and reproduction. Hormones control these processes, and when certain contaminants act as endocrine disruptors, they disturb normal regulatory function (NIEHS, 2015, Endocrine Disruptors). Endocrine-disrupting chemicals have been linked to diseases and disabilities including IQ loss, diabetes, child and adult obesity, and male infertility (Trasande, 2015, Estimating Burden). Research on endocrine-disruption is still a fairly new field, so many potential negative health and environmental effects, including long-term consequences for aquatic ecosystems, different human and wildlife sensitivities, and underlying chemical mechanisms, remain unknown (Sumpter, et al., 2008).

In the short-term, adverse ecosystem effects of pesticides have been observed in wildlife, particularly small fish and amphibians. A 2006 study demonstrated that a mix of pesticides causes frogs to delay metamorphosis and to be of a smaller adult size (Hayes, 2006). These developmental changes can result in declining amphibian populations (Hayes, 2006). By contrast, frogs that are not exposed to endocrine-disruption pesticides, or are exposed to only one pesticide, are typically larger after a longer metamorphosis (Hayes, 2006).

The Great Lakes also suffer from microbial contamination, originating primarily from sewage and untreated urban runoff. For example, water samples collected at Lake Michigan beaches in 2004 found bacteria from human fecal matter (*Enterococcus* and *E. coli*) in 20% of the water samples taken (Liu et al., 2006). In 2010, 15% of samples from freshwater beaches in the Great Lakes exceeded the maximum *E. coli* standard set by the EPA, indicating the presence of human or wildlife fecal matter that poses a health risk to swimmers (NRDC, 2011, Testing the Waters). Consumption of this contaminated water, including unintentional consumption during swimming or boating, can lead to a variety of diseases, infections and parasites (Liu et al., 2006).

The mixes of long-lasting synthetic pollutants, heavy metals, pharmaceuticals, and pesticides have many unknown outcomes and risks. Precisely how these compounds interact with each other and with the environment is not well understood. More research on these chemical interactions, including their potential long- and short-term health effects for humans and wildlife, is necessary. Ultimately, these pollutants can harm entire populations, not just the individuals that are exposed.



Figure 3. Water contamination from dissolved pharmaceuticals can disrupt hormone processes in wildlife and possibly humans. Research on emerging endocrine-disrupting contaminants is fairly new, and long-term health effects are not fully known. Source: William Duke Photographic Illustration.

Contaminated Areas and Toxic Substances

The most heavily polluted areas are identified as Areas of Concern, which are defined as locations in the Great Lakes region where extensive land and water degradation has occurred that significantly impairs safe use by humans and the ability of native aquatic life to thrive (EPA, Great Lakes AOCs, 2015). The term stems from a 1987 amendment to the U.S.-Canada Great Lakes Water Quality Agreement (EPA, Great Lakes AOCs, 2015). Contaminated Areas of Concern are located on both the American and Canadian territories of the Great Lakes (EPA, Great Lakes AOCs, 2015). In total, 43 Areas of Concern have been designated: 26 located entirely in the U.S., 12 entirely in Canada, and five shared by both nations (EPA, Areas of Concern, 2015).

Mining in the Great Lakes Region

Mining sites are being proposed in Michigan, Wisconsin, Minnesota and Ontario, Canada to extract what is estimated to be over \$1 trillion worth of copper-nickel ores (Center for Biological Diversity, n.d.). However, mining activities could further pollute local waters and create a troubling source of nonpoint source pollution for the Great Lakes.

Mining of heavy metals, such as nickel and copper, often results in the release of sulfur compounds that can cause environmental damage when they react with water and air to become sulfuric acid (Center for Biological Diversity, n.d.). This phenomenon is known as acid mine drainage (Figure 4), which can be difficult to stop once the process begins (Jennings, 2008).

The proposed mines could release millions of tons of hazardous sulfide-containing rock material that would result in this acidic leaching effect (Center for Biological Diversity, n.d.). In addition to the dangerous corrosive effects that the acid compounds would have on the local environment and aquatic wildlife, the



Figure 4. Ohio Valley Mushroom Farm, Acid-Mine Drainage (AMD). Image credit: Jack Pearce, www.flickr.com/photos/jwpearce

acid runoff is known to dissolve heavy metals present in the ground, including lead and mercury, which could further contaminate Great Lakes waters (EPA, What is Acid Mine Drainage, n.d.). The acid might also corrode infrastructure such as bridges, making this threat economic as well as ecological (EPA, What is Acid Mine Drainage, n.d.).

Native American tribes in the Great Lakes region have voiced concerns about the negative implications of metal mining, such as proposed iron mining near Lake Superior, noting that the practice could adversely affect both ecological health and cultural wellbeing (Geertsma, 2014).

Cleaning Up Contaminated Areas and Toxic Substances

Ultimately, the cleanup of Areas of Concern aims to:

- Remove restrictions to Great Lakes resources currently impaired due to contamination or degradation
- Control toxic substances
- Reduce human exposure to contaminants from fish consumption
- Identify emerging contaminants and assess impacts on Great Lakes fish and wildlife

Cleanup techniques vary by site, depending on the nature and extent of pollution and other impairments to human and wildlife wellbeing. Unsafe conditions for fish and water consumption by humans are of particular concern. Common remediation measures include dredging, removing contaminated sediment and habitat restoration, such as improving fish passages, removing dams, and restoring wetlands (Great Lake Interagency Task Force, 2014).

Dredging involves the physical removal of sediment from the bottom of a lake or river and is a common method of addressing toxic contamination. Each year, approximately 5 million cubic yards of bottom sediments are dredged from the Great Lakes and their tributaries (Great Lakes Dredging Team, 2013). For long-lasting pollutants such as PCBs, dredging the sediment can be an important environmental remediation tool. Slightly more than half of the dredged sediment removed from the Great Lakes has enough contamination to require confined disposal, typically in designated disposal facilities (Great Lakes Dredging Team, 2013).

Capping is another tool often used instead of or in addition to dredging. Capping entails placing clean sediment on top of newly dredged sites, on top of contaminant disposal facilities, or on top of toxic sites that cannot be dredged. Capping provides a barrier to prevent and reduce exposure of humans and wildlife to noxious chemicals.

Site improvement through dredging or capping potentially allows for newly cleaned areas to be converted to places of beneficial use, such as nature preserves (Great Lakes Dredging Team, 2013). The Cleveland Lakefront Nature Preserve is an example of a capped and converted disposal facility now providing critical habitat for bird migration, as well as outdoor recreation and education opportunities for local residents (Port of Cleveland, 2015).

To measure success, the number of delisted Areas and the number of beneficial uses restored can be tracked. Use restrictions include impairments such as beach closings, restrictions on water, fish, and wildlife consumption, and loss of habitat. In total, there are 14 different types of restrictions that serve as measurements in determining whether a location should be deemed an Area of Concern. These Areas may have many different kinds of restrictions. Delisting cannot occur until all restrictions have been removed through proper cleanup, remediation, restoration and other efforts required to achieve the desired ecological health and safety goals backed by sufficient monitoring data (International Joint Commission, 2013; EPA, Delisting Principles and Guides, 2001).

During the 25 years preceding the Initiative, only one Area of Concern was cleaned sufficiently to be removed from the list. During Phase I of the Restoration Initiative (2010-2014), however, cleanup measures were carried out in nine Areas of Concern and six of them were delisted (Great Lakes Restoration Initiative, 2015). There are 43 remaining Areas of Concern (EPA, 2015), which will each receive restoration measures during Phase II of the restoration project, with the goal of removing an additional 34 restrictions in the remaining 29 Areas and delisting an additional 10 Areas by 2019, as shown in Figure 5 (Great Lakes Restoration Initiative, 2015).

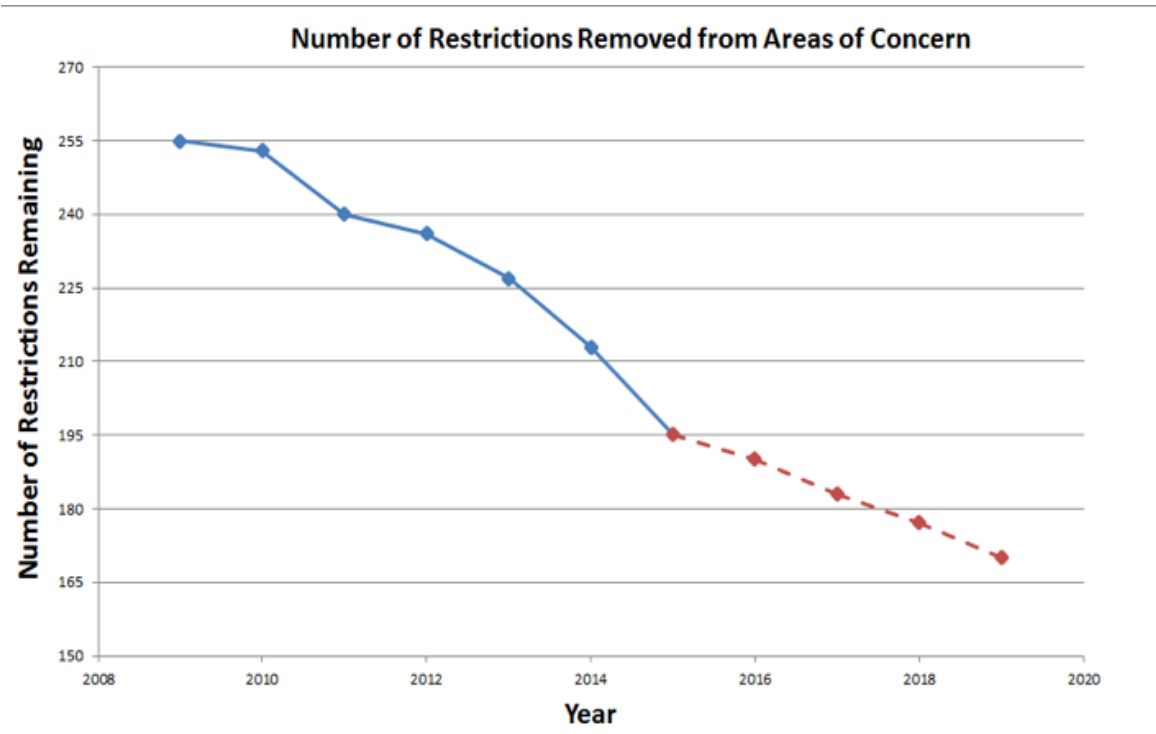


Figure 5. Restrictions removed from Areas of Concern as of 2015. The blue line shows the number of restrictions from Areas of Concern that have been removed from 2008-2014. The red line shows projected number of restrictions to be removed during Phase II of the Great Lakes Restoration Initiative (2015-2019). Note that the ultimate goal is to remove all restrictions and eliminate all Areas of Concern, but this long-term goal will require additional remediation and restoration efforts. Source: Adapted from Great Lakes Restoration Initiative.

The Manistique River is an Area of Concern that is currently being evaluated for delisting. The original remedial action plan identified five restrictions within the area, including restrictions on fish and wildlife consumption, degradation of benthos (organisms living in sediments and near the water bottom, which are vital for aquatic ecosystem health), restrictions on dredging activities, beach closings, and loss of fish and wildlife habitat. The last 1.7 miles of the river has been negatively impacted by waste from paper mills, water treatment plants, and other industrial activities leading to the contamination of sediment by PCBs, oils, and heavy metals. Remedial action involving the removal of contaminated sediments since 2005 eliminated restrictions on degradation of benthos and loss of fish and wildlife habitat. Currently, the focus is on removing restrictions on fish and wildlife consumption and the restriction on dredging activities. Success at this location is measured by the 111,000 cubic yards of contaminated sediment dredged and removed thus far, which is enough to consider the site for delisting. Additionally, water quality improvements since 1995 have resulted from increased treatment of incoming wastewater (EPA, Manistique River, 2015).

While dredging is a common and effective method used in many remediation efforts, it can also be a controversial management practice (PIANC, 2004). Dredging changes the physical composition of the sediment, potentially causing negative ecological effects. For example, dredging sediment disrupts the invertebrates living at the bottom of the lake or river, which decreases the food supply for organisms higher up in the food chain, such as fish (PIANC, 2004). Ecosystem recovery from dredging can take one to three years, depending on the amount and kind of sediment that was dredged (Borja, 2010). The dredging process also inevitably releases some polluted sediment back into the water, increasing contaminant concentrations in the short term; subsequent uptake by fish

and shellfish can pass these contaminants on to higher-level predators and potentially to humans (PIANC, 2004).

Dredging can also cause problems associated with the transport of toxic materials. Transferring toxic sediment to a facility away from the contaminated site is much more costly than placing the sediment in an onsite location (EPA, 2014, Dredging & Excavation). Additionally, moving contaminated sediments can result in spills during transport, which can release the pollutants back into the environment, potentially increasing human and wildlife exposure to contaminants and making conditions worse than when the pollutants were buried in sediment (Renholds, 1998).

Determining the type of investment to put into Great Lakes restoration can also be controversial. For contaminated sediment, there may be conditions under which it is better to leave the pollution in the ground where it may degrade naturally, keeping the pollution mostly confined to the sediment instead of releasing it into the water column (Schmidt, 2001). However, the pollution will persist in the sediment, posing potential long-term problems. Additionally, some contaminants, such as heavy metals, do not decompose further and will continue to pose health risks as long as the pollutants remain in the ecosystem.

Scientific Controversies: Mercury Pollution and Health Safety Levels

Another controversy related to pollution from toxic compounds involves the calculation and perception of risk. Coal-fired power plants, as depicted in Figure 6, are the largest source of mercury contamination in the U.S., with over 140 plants located within and surrounding the Great Lakes watershed (Cmar, 2012; National Wildlife Federation, 2015, Mercury Pollution). Mercury levels in the Great Lakes are enough to cause developmental defects and neurological problems in children who consume fish (Safer Chemicals, Healthy Families, n.d.). While mercury poisoning can potentially impact many populations in the Great Lakes basin, it most often occurs in low-income and indigenous communities, making mercury pollution a social justice issue as well as a public health issue, since these communities depend upon the Great Lakes for sustenance (Tyson, 2012).

Opinions vary over what concentrations of toxic substances in fish are considered safe for human consumption. For example, the U.S. federal standard for the maximum dose of mercury allowed in fish is 1 ppm (International Joint Commission, 2004). This differs from the amount allowed by the Michigan and Illinois state health departments, which is 0.5 ppm (International Joint Commission, 2004). In Canada, the mercury threshold is 0.2-0.5 ppm, depending on type of fish and amount



Figure 6. Coal-fired power plants are a major contributor to mercury contamination throughout the Great Lakes basin. Source: GreenFaith.

consumed (International Joint Commission, 2004). Meanwhile, the World Health Organization standards identify 0.5 ppm as safe for non-predatory fish and 1 ppm as safe for predatory fish (International Joint Commission, 2004).

The United States government sets federal standards for safe mercury concentrations through the EPA. The EPA and the National Research Council (part of the National Academy of Sciences) reviewed several studies about mercury effects on children to determine the maximum safe level, taking into account body weight, age and exposure concentration (EPA, 2014, Methylmercury). However, the validity of the EPA threshold has been questioned, since the agency has been accused of loosening standards for mercury under political and industry pressure from coal company lobbyists (Hightower, 2009). State governments may also set different standards as long as they are more stringent than the U.S. federal government's maximum permissible levels. In 2004, Canada strengthened its mercury safety standards following a review of Canadian fish consumption habits (Health Canada, 2011). The World Health Organization examines research and publishes evidence on mercury impact levels, but its assessments are based on global research and are meant to pertain to populations around the world (WHO, 2013). Controversy over which levels of mercury are safe for human consumption thus demonstrates a lack of agreement and consistency in evaluating and communicating risk, which can vary regionally and across different populations.

Nutrient Runoff Pollution and Algal Blooms

The largest source of nutrient pollution impacting the Great Lakes is phosphorus-rich runoff from agricultural land (International Joint Commission, 2014). The Great Lakes region supports 25% of Canada's agricultural capacity and 7% of the United States', and resultant runoff from these lands generally carries nutrient-laden fertilizer and manure into surrounding waters, as shown in Figure 7 (EPA, 2012, Great Lakes: Basic Information).



Figure 7. Non-point source pollution, such as agricultural runoff, contains high levels of nitrogen and phosphorous. These nutrient loads can contaminate waterways and lead to harmful algal growth. Source: Environmental Defense Fund.

Treated and untreated wastewater from urban centers also contributes significantly to the pollution of the Great Lakes, with major U.S. cities including Detroit, Cleveland, and Buffalo discharging wastewater, stormwater, and occasional sewage overflow into the Great Lakes (EPA, 2015, Nutrient Policy Data). Roughly 100 billion gallons of stormwater runoff are generated each year in southeast Michigan alone, containing 100 tons of phosphorus and 34,000 tons of sediment (Southeast Michigan Council of Governments, 2013).

These elevated nutrient levels feed algae, resulting in algal blooms that have two harmful effects (Koslow, 2013). First, when the algae die, bacteria that decompose them consume large quantities of dissolved oxygen in the water, reducing oxygen availability for fish and other organisms, and creating a condition called hypoxia that creates “dead zones.” In the central basin of Lake Erie, algal blooms have caused hypoxic conditions that worsen throughout the summer season every year since 1985 (EPA, 2013, Dissolved Oxygen Depletion). In 2011, Lake Erie experienced a record-setting algal bloom, three times the size of any previously observed and spanning nearly 120 miles (Michalak et al., 2012). A second negative effect is that some of these algal blooms include types of cyanobacteria that produce toxins. One type of cyanobacteria, called *Microcystis*, produces toxins called microcystins that have killed fish, mammals, and birds (WHO, 2015).

Public water systems are also affected, since these toxins can cause liver damage in humans, which is a major health concern for the 26 million people depending upon the Great Lakes for drinking water (WHO, 2015). In 2014, microcystin concentrations exceeded safe levels in parts of Lake Erie, resulting in a two-day drinking water ban for the city of Toledo, Ohio (NASA, 2014). During toxic algal blooms, the additional cost to water treatment facilities can exceed \$5000 per day (Mangels, 2013).

Algal blooms present aesthetic, public health, ecological, and economic problems because they are unsightly, reduce water quality, clarity and taste, and cause strong odors. These effects, in turn, can deter tourism, discourage aquatic recreation, and lower property values (International Joint Commission, 2014). For example, in 2011 harmful algal blooms in Lake Erie cost the recreational and commercial fishing industries an estimated \$2.4 million (International Joint Commission, 2014).

As of 2011, the Great Lakes region annually received an estimated 47 million pounds of phosphorus runoff into watershed outlets from urban and agricultural sources, 22 million of which came from cultivated cropland (NRCS, 2011). About 250 million gallons of untreated urban runoff are expected to be captured or treated by Initiative-funded projects during Phase II; the total urban phosphorous contributions are estimated to be about 16 million pounds (Great Lakes Interagency Task Force, 2014; NRCS, 2011).

Reducing Nutrient Runoff and Algal Blooms

The Initiative seeks to reduce nutrient runoff in urban areas by establishing various kinds of watershed management projects, including natural stormwater retention and treatment locations that rely on vegetation to take up and filter excess water and suspended pollutants (Southeast Michigan Council of Governments, 2013). Through transpiration, the process by which water is drawn up out of the soil, passed through plant tissues, and then finally evaporated out through leaves, excess stormwater is naturally filtered and released. By establishing bioswales, or stretches of vegetated land typically along roads (Figure 8), as well as tree trenches that offer similar benefits, greening programs aim to reduce overall runoff volume and suspended pollutants by up to 50% (Southeast Michigan Council of Governments, 2013).

The Initiative additionally seeks to implement nutrient reduction practices in targeted agricultural watersheds throughout the Great Lakes region. The practice of conservation agriculture can reduce negative environmental impacts of nutrient runoff and increase agricultural yields, resulting in more profitable productive land in the long-term. Conservation strategies include buffer strips, cover crops, no-till planting, and two-stage ditches.

Buffer strips are the agricultural analogue to bioswales in urban areas. They are areas between croplands planted with permanent vegetation that slow water runoff and trap sediment, fertilizers, pesticides, pathogens, and heavy metals. In addition to creating windbreaks and shelter for livestock, they have the capacity to remove up to 50% of fertilizers and pesticides and 75% of sediment runoff when installed and maintained properly (NRCS, 2015).

Cover crops are grasses or legumes planted in the off-season when soils would normally be bare. Their root systems maintain soil structure and protect soils from erosion that can be caused by wind and precipitation. Cover crops also contribute to soil fertility by adding organic matter when they are reintegrated into the soil before planting the following year (Minnesota Department of Agriculture, 2015).

Conservation tillage, or “no-till” planting, involves direct seeding of the main crop with minimal soil disruption by minimizing tillage. This maintains soil structure and increases surface residues, thus reducing erosion (NRCS, 2009). Two-stage ditches are contoured drainage ditches in which the first ridge is planted with grasses and vegetation to improve infiltration and absorption of runoff, nutrients, and pesticides. The main channel at the base of the ditch is deeper which increases overall floodwater retention capacity of the system. Two-stage ditches also improve bank stability and help mitigate downstream flooding (Vollmer-Sanders et al., 2012).

Phase II of the Initiative further aims to reduce agricultural phosphorous runoff by helping farmers determine the appropriate source, rate, and time to



Figure 8. Urban bioswales can absorb significant amounts of excess stormwater and associated pollutant runoff. Source: Courtesy of the U.S. EPA.

Sustainable Farming to Reduce Nutrient Pollution

Incentive programs through the Natural Resource Conservation Service and other government and non-government organizations encourage farmers to adopt conservation strategies to reduce erosion and nutrient runoff from their fields. These programs are often “activity-based,” where program funds are used to share farmers’ cost of implementation of an agricultural conservation production method, such as using buffer strips. Alternately, the incentive can be performance-based, in which farmers receive payments for every unit of diminished runoff and erosion reduction in their fields (Great Lakes Protection Fund, 2015). By shifting agricultural practices through economic incentives for farmers, these programs can reduce the strain major production alterations can have on their bottom line. Many of these practices, once implemented, save on costs in the long run, as natural ecological processes make production more efficient and sustainable (Great Lakes Protection Fund, 2015). In the Lake Erie basin, nutrient reduction methods initiated during Phase I have helped farmers save \$13-16 in fertilizer costs per acre and reduced phosphorus runoff by 21 pounds per acre on average (Great Lake Restoration Initiative, 2014, Action Plan II).

apply nutrients to their crops. Public outreach programs encourage farmers to plant cover crops and consider no-till farming. Phase I provided farmers with financial and technical resources to reduce runoff and control soil erosion (Great Lakes Interagency Task Force, 2014).

To quantify the Initiative's success in the long-term goal of reducing nutrient runoff contributing to algal blooms, measurements include: (1) the pounds of phosphorous reductions, (2) the number of acres of nutrient and sediment reduction projects, and (3) the millions of gallons of treated or captured runoff (Great Lakes Interagency Task Force, 2014).

Within five years, programs enacted during Phase I more than doubled the number of acres of farmland enrolled in agricultural conservation programs in priority watersheds to over 200,000 acres (Great Lakes Interagency Task Force, 2014). While the Initiative has no baseline for the pounds of phosphorous reductions, the goal is to reduce phosphorous from targeted watersheds by 1,070,000 pounds by 2019 (Great Lakes Interagency Task Force, 2014).

In terms of reducing untreated runoff from urban watersheds, projects seek to reduce sediment, nutrient, toxin, and pathogen runoff through the use of green infrastructure (e.g., bioswales) and watershed management projects. The Initiative does not have a baseline for the volume of untreated urban runoff captured or treated via the Initiative previously, but aims to reach 250 million gallons by 2019 (Great Lakes Restoration Initiative, 2014, Action Plan II).

One place where efforts to reduce both agricultural and urban runoff are currently underway is the Lower Fox River Watershed in Wisconsin. Funding from Phase I of the Initiative has allowed for the protection of almost 20,000 acres of farmland, five percent of this approximately 400,000-acre region (Wisconsin Department of Natural Resources, n.d.; Healing Our Waters, 2013). Additionally, a new wastewater treatment plant, located in the Lower Fox Watershed by Green Bay, Wisconsin, is making efforts to cut the amount of phosphorous discharge by 8,710 pounds from the 26,059-pound total discharged from this plant each year (Hafs & Finney, 2014). While this is a 33% reduction in discharge from this plant, 8,710 pounds is less than 1% of the total amount of phosphorous entering Green Bay from the Lower Fox River Basin, so a comprehensive, region-wide effort is necessary to significantly reduce nutrient pollution moving forward (Hafs & Finney, 2014).

Damage to Native Species and Habitats

The Great Lakes region is home to hundreds of species of plants and animals whose populations have been reduced to the point where they are at significant risk of extinction (Great Lakes Interagency Task Force, 2014). The region's biodiversity includes over 200 globally rare plants and over 40 wildlife species that have been found exclusively in the Great Lakes region, such as the copper redhorse fish and the Kirtland's warbler (Great Lakes Interagency Task Force, 2010). Many of these species are of significant ecological, economic, recreational and cultural significance to the area and its people. The lake sturgeon, for instance, a native fish species of particular importance for Native American tribal ceremonies and harvests, is threatened due to overfishing and habitat loss (Great Lakes Indian Fish and Wildlife Commission, 2015).

The ecosystems of the Great Lakes are primarily being degraded by three causes: agriculture, urban development, and residential shoreline development. Large areas of marsh and coastal wetlands were lost then they were drained to create agricultural land (Michigan Natural Features Inventory, 2003). In the Great Lakes basin, an estimated 50% of wetland area has been lost between the 1780's and the mid-1980's (Environment Canada, 2011, State of the

The Lake Sturgeon: A Threatened Cultural and Ecological Treasure

Lake sturgeon (*Acipenser fulvescens*) is an important native fish in the Great Lakes, not only from a biological perspective, but also for historical and cultural reasons. Indigenous tribes of the Great Lakes region depend on the sturgeon for subsistence, as it is the largest fish in the freshwater system. Annual ceremonies and celebrations, such as the Shivaree, have evolved around the sturgeon harvest season and spawning (Sturgeon For Tomorrow, n.d.). Due to overfishing, habitat degradation, dam construction and water pollution, the species was declared threatened or endangered in 19 states across the U.S., and extensive restoration efforts are now carried out in coordination with indigenous communities to preserve this fish (Figure 9).

For example, at the St. Louis River near Lake Superior, an Area of Concern undergoing cleanup efforts, biologists have recently documented naturally spawning sturgeon for the first time in decades, following several years of reintroducing the species into this water body (Minnesota Sea Grant, 2013). Additionally, 40,000 square feet of artificial reef construction in the St. Clair River north of Detroit has successfully attracted Lake Sturgeon to the region and biologists are now studying the location to determine if these efforts will contribute to increasing population numbers (Healing Our Waters - Great Lakes Coalition, 2012).



Figure 9. A 74-pound adult lake sturgeon being studied by fishery biologists from the U.S. Fish and Wildlife Service and the Great Lakes Indian Fish and Wildlife Commission. Source: USFWS Midwest.

Great Lakes; Tip of the Mitt Watershed Council, 2015). Provisions to U.S. environmental law issued in the 1970's now protect America's existing wetlands from further destruction and support improvement and restoration whenever feasible (EPA, Protection of Wetlands).

The practice of filling, draining and developing wetland areas to facilitate agriculture and other human land use activities, such as urbanization, has historically been commonplace. Southern Ontario has lost close to 80% of original wetlands, and losses in Ohio are estimated at 92% (Fuller, 1995). Along with providing crucial wildlife habitat, wetlands also filter pollutants and buffer floodwaters, thereby supporting adjacent ecosystems. Reduced coastal habitat is of great concern too. Due to shoreline habitat loss, the piping plover, a shorebird native to the Great Lakes, is critically endangered with only 71 breeding pairs remaining in the region (Great Lakes Interagency Task Force, 2014).

Dredging to create harbors near developed urban centers can eliminate wetland habitat, and shoreline alteration for docks by lakeside residents may remove or harm aquatic vegetation. Once the roots of plants have been disturbed, sediments can easily erode resulting in further degradation and wetland loss, threatening ecological stability and increasing the risk of flooding since wetlands are natural buffer zones (Michigan Natural Features Inventory, 2003).

There are an estimated 180 species of native fish in the Great Lakes, and threats to these fish stocks include pollutants, botulism, overfishing, and harm from invasive species (Great Lakes Interagency Task Force, 2010; Great Lakes Interagency Task Force, 2014). Dams and poorly designed and/or degraded culverts can also prevent fish from swimming up rivers and streams, impacting reproduction (Great Lakes Interagency Task Force, 2014).

Restoring Habitat to Protect Native Species

To address degradation of natural land, water and air quality and negative impacts on wildlife species in the region, the Initiative promotes protection, restoration, and enhancement of habitat to help sustain healthy populations of native species (Great Lakes Restoration Initiative, 2014, Action Plan II). Previous success is evidenced by the 600 projects and over 100,000 acres managed in support of this goal. Measurements of progress include the miles of reopened tributaries and restored shoreline, acres of protected, restored, and enhanced wetlands, and the number of delisted endangered species (Great Lakes Restoration Initiative, 2014, Action Plan II). During Phase I, over 3,400 miles of rivers were reopened, 500 fish barriers were removed, 100,000 acres of wetlands and 48,000 acres of other habitat were restored in the Great Lakes Basin (Great Lakes Restoration Initiative, 2015). Phase II of the Initiative aims to reopen an additional 14,000 miles of tributaries, restore and enhance 875 miles of shoreline, 164,000 acres of coastal wetland, and 835,000 acres of other habitats by 2019 (Great Lakes Restoration Initiative, 2014, Action Plan II).

The Arcadia Marsh has been impacted by heavy railroad construction, agriculture, and river diversion. The Arcadia Marsh Fish Passage and surrounding waterways are undergoing a restoration project, aiming to restore ten miles of fish passage and 203 acres of coastal marsh in the region. Restoring fish passages in the region will allow for fish like the brook trout or slimy sculpin to expand into new areas and increase their population sizes (Mays, n.d.). Changes in land use caused the marsh's watercourses to become shallow and heavily congested with sediment. The area also was reported as experiencing "alarming levels" of invasive plant species in the marsh, including giant reed (*Phragmites*) and reed canary grass. Restoration efforts have focused on restoring water flows in order to help facilitate the growth of adversely affected native populations (Morris, 2013).

Projects like habitat restoration at Arcadia Marsh can contribute to the recovery of threatened or endangered species populations. During Phase I, the Lake Erie water snake was removed from the federal endangered species list as a result of projects supported by Initiative funding. The U.S. Fish and Wildlife Service (USFWS) originally listed the snake as threatened due to low population numbers resulting from habitat loss by shoreline development and intentional eradication. Without protection, the Lake Erie water snake may have been totally eliminated from the islands offshore of western Lake Erie. With permanent habitat protection by minimizing habitat loss due to shoreline construction, however, the population size increased and exceeds target population recovery goals. As a result, the USFWS determined the population is healthy, is likely to remain healthy, and needs only monitoring over the next five years (USFWS, 2015, Lake Erie Water Snake).

Another solution to native habitat and species loss is the restoration of natural stream complexity. The Avon Creek restoration project, which flows into a tributary of Lake Michigan, seeks to improve water, wetland and streambank quality by restoring natural stream curves, creating pools and riffles (shallow, rocky stretches of water with slower velocity and higher turbulence), adding wood debris and reducing erosion through reforestation (USFWS, 2013). For fish, channel complexity provides a refuge and nursery area that is safe from predators and is protected from strong currents and flood events. Reduction of erosion minimizes the amount of sediment in the water. Lower

sediment loads can boost photosynthesis of freshwater algae and submerged plants by allowing more sunlight to penetrate the water column, thereby improving plant development and subsequently, refuge and food availability for fish and other riparian organisms (Kemp et al., 2011). Reduced sediment inputs can also mitigate instances of anoxia, which can kill fish and other aquatic species due to low dissolved oxygen levels (Billman et al., 2012).

Infrastructural design can reconnect rehabilitated land to adjacent lands and waters to allow passage of native fish. Culverts, artificial tunnels through which water is able to flow beneath roads, are a major component of the Initiative. When improperly installed, however, culverts can prevent fish from accessing critical upstream habitat (Great Lakes Basin Fish Habitat Partnership, 2015). Initiative funding has started the process of restoring and supporting brook trout mobility and spawning in Sawmill Creek, a tributary of Lake Superior, through the replacement of two 72-inch diameter culverts. Old culverts will be replaced with boxed culverts, which maintain the natural course of the stream, allow natural stream substrate to form (gravel, sand, rock, mud, etc.), and improve water flows across a range of seasonal variation (Great Lakes Basin Fish Habitat Partnership, 2015).

Threat of Invasive Species

Over 180 invasive and non-native aquatic species have entered the Great Lakes region through a variety of means, including recreational boating, harmful fishing practices, shipping operations, and illicit wildlife trade (Great Lakes Interagency Task Force, 2014). Invasive species are species with expanding populations that cause damage to local environments (National Wildlife Federation, 2015). They result in ecological, economic, recreational and public health problems.

Invasive quagga and zebra mussels have proliferated throughout the U.S., reaching population densities as high as 60,000 per square yard, causing significant ecological harm (NRCS, 2007). These mussels selectively feed on non-toxic algae, exacerbating harmful algal blooms by decreasing competition (Michalak et al., 2012). Zebra mussels have eliminated up to 90% of Lake Erie's native mussels since their introduction in the 1980's (NRCS, 2007).

Invasive species can prey on native species or adversely affect their survival. For example, native bivalves, such as the endangered Higgins' eye pearly mussel, are often found partially encrusted by invasive zebra mussels. The invasive mussels are competing with the native mussels for space and hindering the native mussels' ability to take in nutrients from the water or burrow in sediment (USFWS, 2012, Higgins' Eye).

Invasive Species in Clark Township

Clark Township is a small fishing and vacation community located on the shores of Lake Huron in Michigan, and 40% of the township's 2000 residents make their living by providing services to the thousands of tourists visiting the community every year (Great Lakes Coastal Resilience Planning Guide, 2014). However, the future of Clark Township's tourism industry is in jeopardy due to the invasive weeds Eurasian Watermilfoil and *Phragmites*. Since 2007, the community has spent over \$600,000 on invasive species control (Great Lakes Coastal Resilience Planning Guide, 2014). In collaboration with the Initiative, the community has employed the help of a native beetle called the Eurasian watermilfoil weevil. This approach has had varied success against the invasive weed, but has at times resulted in reducing growth of the Eurasian watermilfoil by up to 85% over a 4-year period (Great Lakes Coastal Resilience Planning Guide, 2014). Although the weevil is not a quick fix or single solution for the community's invasive species problem, it is an integral component of the community's strategy to protect native habitats and keep their tourist economy thriving.

A variety of invasive plants have displaced native species as well, causing onshore erosion and undesirable conditions for lake recreation (EPA, 2011, Dioxins). Native plants with fibrous roots stabilize regional soils, while invasive plants with taproots do not (USFWS, FAQ About Invasive Species, 2012). Furthermore, Eurasian watermilfoil, an aggressive invasive aquatic plant, forms thick underwater mats that interfere with aquatic recreation and boating (EPA, 2014, Lake Superior Invasive Species Prevention Plan).

Another invasive species affecting the Great Lakes is the European strain of the giant reed, *Phragmites australis*. It can become the dominant vegetation across large wetland areas because it grows very densely and can displace other plants. Additionally, it can impact native plants by producing an acid that breaks down the roots of competitors. This acid degrades in sunlight to produce a second acid that further damages competing native plants. *Phragmites* impacts wildlife habitat by decreasing the nesting area for some birds and outcompeting native plants that are food sources for several animals (University of Delaware, 2009, Changing Climate).

Invasive species can also have indirect effects by altering food webs and environmental conditions. Invasive species can change abiotic conditions such as light levels and nutrient levels (National Wildlife Federation, 2015). In the Great Lakes, small crustaceans of the genus *Diporeia* were once a main food source for native fish because they were abundant and high in fat. Now, invasive quagga mussels consume large amounts of phytoplankton and produce waste products that lower the water quality. Although the exact mechanism for the decline of *Diporeia* crustaceans is not clear, their populations have decreased dramatically, leading to an unprecedented decline in the population of large fish such as lake sturgeon (Environment Canada, 2011).

The economic impact of invasive species is extensive, affecting commercial and sport fishing, recreational activity, and municipal facilities. The estimated median economic loss per year from invasive species, in lost consumer surplus or in actual cost, was \$138.3M; this includes \$106M from losses in sport fishing, \$5.3M from losses in commercial fishing and \$27M in operating costs to Great Lakes facilities due to invasive mussels clogging critical infrastructure (Rothlisberger et al., 2012). Since the fishing industry in the Great Lakes generates \$7 billion annually in revenue, invasive species must be treated as an economic and an ecological threat (Lubetkin, 2014).

Invasive Species Management and Control

The Initiative has three main objectives regarding invasive species within the Great Lakes region: (1) preventing new introductions of invasive species, (2) controlling established invasive species, and (3) developing control technologies and improving management techniques. Control and prevention measures include the installation of physical barriers, application of herbicides or pesticides, and biological controls. The ultimate goal is for the Great Lakes to have no self-sustaining invasive species populations. To measure progress, the number of projects blocking invasive species entry, the number of controlled invasive species, and the number of acres and/or shoreline miles protected by the Initiative for this purpose are all viable metrics (Great Lakes Interagency Task Force, 2014).

In Phase II, targeted invasive species will continue to be monitored and controlled. Aquatic Nuisance Species Management Plans developed by state agencies and tribal communities will be also supported by federal agencies and Initiative funds (Great Lakes Interagency Task Force, 2014).

Collectively, these projects aim to reduce, control and prevent invasive species by:

- Conducting rapid response actions or exercises (e.g. mobile electric dispersion barriers)
- Blocking pathways for introduction of new aquatic invasive species into the Great Lakes ecosystem
- Conducting early detection monitoring activities
- Developing control technologies and refining management techniques

Federal agencies and their partners controlled 15 invasive species populations during Phase I, meaning target population levels have been maintained or reduced, and protected 36,000 acres in terms of invasive species management, including threats from *Phragmites* and Eurasian watermilfoil (Great Lakes Restoration Initiative, 2014, Action Plan II). The Initiative designates a measure of progress for this focus area as the amount of land controlled or protected by Initiative-funded projects. Protected acres in this sense can be defined as habitat that is guarded from invasive species encroachment (Healing Our Waters - Great Lakes Coalition, 2012).

During Phase I, a specific focus was preventing the Asian carp from reaching the Great Lakes. Electric fences are a developing solution to prevent the establishment of the invasive Asian carp in the Great Lakes (Figure 10). The invasive carp can grow prolifically and outcompete native species of fish, thereby posing a significant threat to the Great Lakes fishing industry and ecosystem (Lubetkin, 2014). Yet possible solutions to the potential invasion have been the subject of much debate. Electric fences are being used by the U.S. Army Corps of Engineers to stop the spread of Asian carp into the Lakes through the Chicago Sanitary and Ship Canal, an artificial passageway built to connect the Mississippi River to the Great Lakes basin (Lubetkin, 2014; Work Group of the Lake Superior Lakewide Action and Management Plan, 2014). The barrier creates an electric field that repels fish of all sizes, thereby preventing them from passing through (Work Group of the Lake Superior Lakewide Action and Management Plan, 2014). This management technique, however, is controversial because effectiveness is uncertain.

Successful control of the invasive and parasitic sea lamprey was the result of testing 6,000 chemical compounds to find those that best control sea lampreys without harming other species (Great Lakes Restoration Initiative, 2014, Action Plan II). The program has been underway since 1955, but continuing efforts in the future will expand the use of barriers and traps as an alternative to chemical control methods. According to the Great Lakes Fishery

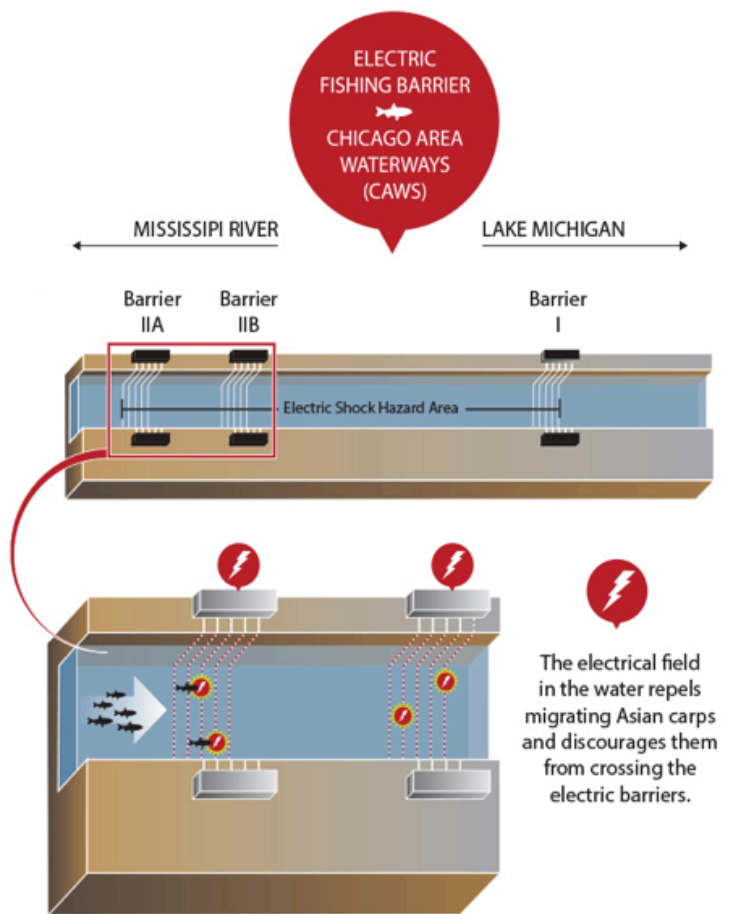


Figure 10. Electric Dispersal Barriers are one method to prevent the passage of invasive Asian carp into the Great Lakes. Credit: Invasive Species Centre.

Commission, the U.S. Geological Survey control program has diminished populations of sea lamprey by up to 90% in most locations throughout the Great Lakes using lampricides, barriers, traps, pheromones and alarm cues (Great Lakes Fishery Commission, n.d.).

In addition to effectively controlling the spread of invasive animals, chemical means can also be used to combat invasive plants. The most common herbicides available are imazapyr and glyphosate, which are sprayed onto stands of *Phragmites* and purple loosestrife (*Lythrum salicaria*), two of the most harmful invasive plants in the region. Both glyphosate and imazapyr destroy the plant by preventing certain amino acids from forming, thereby inhibiting growth (Tu et al., 2001). Following herbicide application, targeted areas are subsequently burned to destroy any remaining invasive vegetation and to enable native plants to return more quickly (Great Lakes *Phragmites* Collaborative, 2013). In a controlled study conducted at the Lake St. Clair Wetlands, which sits along the waterway connecting Lake Erie and Lake Michigan, it was found that application of these pesticides in conjunction with burning reduced *Phragmites* cover by more than 85% for at least two years (Getsinger et al., 2013). Other studies give slightly more conservative measurements of 75% in reduction of plant cover (Getsinger et al., 2013).

Use of pesticides for invasive plant control can be controversial, however, as some types of commonly used herbicides can be highly toxic to fish species (Sustainable Baby Steps, 2014). Glyphosate also kills native plants (San Francisco Estuary Invasive Spartina Project, 2005). In March 2015, the International Agency for Research on Cancer announced that evidence suggests glyphosate is “probably carcinogenic” to humans (Cressey, 2015).

Another invasive species management tool is the use of a biological control, which involves introduction of one species to control another species that is invasive, provided proper research is conducted to minimize possible unintended effects prior to implementation. The Eurasian watermilfoil weevil is one example. Capable of burrowing into the vascular structure of the plant, the weevil kills the invasive Eurasian watermilfoil plant by inhibiting the plant’s ability to reproduce (Groves et al., 2010).

Invasive Eurasian watermilfoil in Cedarville Bay, in Northern Lake Huron, experienced significant declines following the release of Eurasian watermilfoil weevils as a biological control method. At one site, project researchers recorded a 95% reduction in Eurasian watermilfoil plant density 14 months following the release of 13,000 weevils. Comparatively, researchers recorded a significantly smaller 15% reduction in Eurasian watermilfoil plant density after 14 months in a nearby control location where the weevils were not released (Smith, 2010). Despite recorded successes, effectiveness can vary significantly from project to project and outcomes are difficult to predict, yet biological control projects can be implemented fairly cheaply and with minimal effort (Groves et al., 2010).

The primary concern with biological controls is that it is difficult to evaluate the potential long-term effects (Osborne, 2003). Despite this risk, biological control is being utilized in the management of the purple loosestrife, an invasive European plant that degrades wetland quality by suppressing the native plant community and degrading habitat for animals (Blossey, 2002). Dense purple loosestrife establishments can also impede water flow (Blossey, 2002).

To control the spread of purple loosestrife, three exotic European species of beetle have been released in North America, with the potential to release more if the beetles prove to be successful (Seagrant, 2015). It is estimated that it will take 10-20 years before the beetle populations are large enough to be effective (Seagrant, 2015). However, if the beetles end up having a negative impact on the region, it will be difficult to control the already established beetle populations.

An analogous uncontrollable biological introduction event occurred in the 1970s, when U.S. biologists released an Asian ladybug to control aphid populations (Stewart, 2005). It worked in reducing aphid numbers, but also significantly reduced the population of native ladybugs, which also feed on aphids (Stewart, 2005). The potential for biological control agents to have unforeseen or unintended environmental consequences makes this type of management controversial (Osborne, 2003).

Conclusion

There are many factors negatively impacting the Great Lakes environment. Toxic substances, nutrient pollution, algal blooms, habitat destruction, loss of native species and proliferation of invasive species are all regional environmental problems that must be actively managed to improve ecosystem health for current and future generations.

The Great Lakes Ecological and Economic Protection Act of 2015 seeks to implement numerous solutions to address the widespread environmental ills in this region. The Act will provide the Great Lakes Restoration Initiative with additional funding through 2019 to continue projects implemented during Phase I (2010-2014) and to begin new projects that further improve the region's environmental health. The Act will permit continued actions targeting recovery and maintenance of Great Lakes' chemical, biological and physical integrity to further restore health and ensure economic productivity of the Great Lakes basin.

The Act's effectiveness can be gauged using the best scientific data and evidence-based management practices available. Building upon past success while anticipating and reacting to new challenges and solutions is vital. Designated measures of progress will evaluate the effectiveness of individual Initiative projects. Phase I achievements and proposed Phase II measures will serve as a framework to develop specific goals and metrics.

Understanding the evidence, costs and benefits of current and emerging solutions is imperative in restoring the health and integrity of the Great Lakes. Protection of this environmental, economic and cultural resource requires an ongoing understanding of the natural mechanisms underlying ecosystem functions, as well as a scientific understanding of the causes of environmental degradation that has created health risks. Equipped with knowledge and best practices from Phase I, continued evaluation and monitoring of ecological and public health measures through Phase II will further improve the productivity, longevity and sustainability of the Great Lakes region to benefit both humans and wildlife.

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