The Great Lakes Collaboration Implementation Act Of 2009

FINAL REPORT POLICY ANALYSIS OF HR 500

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Executive Summary

Fresh water is one our most valuable resources. It provides numerous benefits: clean water for drinking, fish for sport and consumption, a medium for transportation, irrigation for agriculture, and many others. The Great Lakes – Michigan, Eerie, Ontario, Superior, and Huron – make up the largest surface freshwater system on Earth, serving more than 35 million people living in the Great Lakes basin. The scale of these benefits make it essential that we preserve this water system for current and future generations so we may continue to enjoy each of the Great Lakes' resources. To accomplish this goal, legislation was designed to regulate and reverse harmful anthropogenic activities and to aid in the remediation of the Great Lakes.

The Great Lakes Collaboration Implementation Act of 2009, or HR 500, attempts to address fundamental environmental issues affecting the health of the Great Lakes. The bill identifies four threats to the ecosystem. The first area of concern is invasive species. Invasive species are foreign species that spread rapidly when introduced into new ecosystems. They are detrimental because they alter population dynamics and damage infrastructure. The second area of concern is toxic substances. Certain toxins from anthropogenic point and non-point sources can enter and persist in the Great Lakes, eventually being absorbed by biota. Toxics can then affect the health of organisms and human beings that are exposed to the contaminants. The third area of concern is wastewater management. Wastewaters from wastewater runoff and outflow from urban and agricultural areas contribute contaminants to the Great Lakes' ecosystems and biota, causing eutrophication and disease. Lastly, the fourth area of concern addressed by HR 500 is wetland loss and degradation. Human activities both direct and indirect are damaging the health of wetlands. The loss of these wetlands reduces the buffering capacity these regions have on extreme weather and pollution and it also destroys many endangered species' habitats.

HR 500 takes a proactive and collaborative stance at addressing environmental issues of the Great Lakes. First the legislation seeks to prevent new environmental issues from forming and becoming well rooted problems. Such preemptive measures are decisive in preventing future outbreaks of invasive species. If such an outbreak is not addressed early, the problem becomes increasingly difficult to remediate once the organism establishes itself and begins to thrive. Additionally, in line with its preventive measures are goals to perform more extensive monitoring programs that are capable of detecting environmental issues in their early more manageable stages. Taking this stance will ensure that the environmental issues affecting the Great Lakes will be discovered before they reach critical and possibly irreversible levels. A second dimension of HR 500 is collaboration. It plans to include more stakeholders in the planning and remediation process. This not only increases awareness on environmental issues affecting the Great Lakes, but also increases the success of detecting and monitoring problems by increasing manpower the sharing of knowledge. Furthermore, HR 500 aims to improve monitoring techniques by establishing outcome indicators to determine the success of current remediation projects and help establish best practices for remedial efforts. These goals enable HR 500 to be a strong piece of legislation that can act as a catalyst to solve the environmental problems affecting the Great Lakes.

Although HR 500 establishes a rational strategy to confront environmental issues affecting the Great Lakes, there is potential for controversy among stakeholders and the scientific community. The recommended remediation projects will serve to benefit or harm individual stakeholders. Uneven funding allocations for involved parties will create disagreements concerning remediation outcomes, with each party preferring the action that accommodates and/or enhances their use of the ecosystem. These types of disagreements may revolve around the location and extent of clean-up efforts, wetland enhancements, and sewer-system retrofits that could affect property values or commerce. Consensus among the scientific community is another area of potential disagreement. HR 500 mandates solutions that require the use of a variety of technologies to address environmental issues. However, because of the complexity of environmental issues and the limited amount of data on these technologies, scientists do not agree on the effectiveness of particular remediation efforts. This type of disagreement is warranted since environmental problems can vary dramatically based on region, size, and ecosystem complexity. In order to ensure that the desired results are achieved, HR 500 emphasizes monitoring procedures that track the success of technological and scientific solutions.

The Great Lakes Collaboration and Implementation Act of 2009 emphasizes monitoring through technology, science, and collaboration. These methods will enable continuous data collection on solutions and ensure that solutions are achieving desired results or if they need to be reevaluated. Monitoring efforts will be led by the National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Laboratory, and the Environmental Protection Agency (EPA). Furthermore, because of the interplay between the four environmental problems being addressed, monitoring efforts will be designed to best address each desired outcome, and to evaluate outcome-specific results. Due to invasive species' resilience to eradication measures, monitoring will focus on quickly identifying new introductions. The desired outcome for such programs must be minimizing new introductions and controlling existing populations. Toxic substances pose additional challenges to monitoring. The regions they affect and the stakeholders involved can vary drastically on a case-by-case manner. Therefore, monitoring efforts for toxic substances are tailored to best evaluate each particular solution. For monitoring wastewater discharge, HR 500 focuses primarily on the effectiveness of water treatment facilities. The assessment involves monitoring coliform levels, bacteria that is often used as a sanitary indicator of food and water (EPA Great Lakes Monitoring Website, 2009). Lastly, in terms of monitoring solutions to address wetland loss, the Act monitors improvements in the quality of ecological services that wetlands provide as well as the trends in wetland losses. Ecological services of wetlands are functions such as processing nutrients, harboring wildlife, and storing floodwater (Quammen, 1986).

Using this end-to-end approach to address environmental problems affecting the Great Lakes, the Act is able to succinctly identify threats, develop programs to mitigate or prevent identified threats, and address uncertainties through monitoring.

HR 500, the Great Lakes Collaboration Implementation Act, aims to ameliorate a variety of environmental concerns pertaining to the Great Lakes aquatic ecosystems. These concerns reflected the sentiments of the Great Lakes Regional Collaboration's first conference in 2005, where 1,500 participants gathered to address the environmental issues in the region (House of Representatives, 2006). This bill would represent an important step toward restoring the full services and value of this national treasure.

Largely echoing the Great Lakes Regional Collaboration's suggestions, HR 500 addresses four overarching concerns within the aquatic environment, including the persistence of invasive species, the control of toxic pollutants), wastewater pollution, and wetland destruction.

Invasive Species

Problem Identification & Impacts

The predominant concern pertaining to invasive species is their lack of natural predators in their non-native environment, resulting in rapid population growth. Therefore, once invasive species are established, their burgeoning populations can cause additional competition with native organisms for local resources, disrupting the natural equilibrium within the ecosystem. A species' adaptability, tolerance of a wide range of environmental conditions, and capacity to reproduce quickly also are determining factors in their ability to spread throughout an ecosystem (National Invasive Species Counsel, 2006). It should be noted, however, that not all non-native species to an area are invasive; in fact, most are not.

Estimating the full extent of the environmental damages caused by invasive species, including the number of resulting species extinctions, is difficult because little is known about the estimated 750,000 species in the United States (Pimentel et al., 1999; Raven and Johnson 1992). Nonetheless, about 400 of the 958 species that are listed as threatened or endangered under the Endangered Species Act are considered to be at risk primarily because of competition with, and predation by non-indigenous species (Pimentel et al., 1999; Nature Conservancy, 1996; Wilcove et al., 1998).

The United States Geological Survey (2008) has identified 136 species of invasive algae, fish, invertebrates, and plants that have established themselves in the Great Lakes since the 1800's. These species have caused substantial ecologic and economic damage to the region. Specific attention is given to the Zebra Mussel (*Dreissena polymorpha)*, a freshwater mollusk native to the Caspian Sea, responsible for up to $500 million per year in economic and environmental damages. For example, in 1989, the city of Monroe, Michigan lost its water supply for three days due to massive numbers of Zebra Mussels clogging city water intake pipes (USGS, 2000). Beaches in parts of Lake Erie have also incurred high costs associated with the removal of Zebra Mussel (USGS, 2007).

Case Study: Extirpation of American Native mollusks following introduction of the Zebra Mussel

The Zebra Mussel was originally introduced into the Great Lakes from the ballast water of a cargo ship from the Ponto-Caspian region. It was first observed in Lake St. Clair in 1988, and within 10 years had spread to all five Great Lakes (USGS, 2007). The Zebra Mussel has caused extensive damage to both infrastructure and ecosystems since its arrival.

Invasive Zebra Mussels colonizing a native Unionid Bivalve (*Pyganodon grandis*, Giant Floater). Colonization by the Zebra Mussel reduces the ability for the clam to move, feed and reproduce, leading to death of the host clam in 1-2 years. Image Credit: Phil Myers, Museum of Zoology, University of Michigan, http://animaldiversity.ummz.umich.edu/site/resources/phil_myers/ADW_molluscs3_4_03/zebra_unionid6319.jpg/view.html

Zebra Mussels reproduce prodigiously, and colonies can be as dense as 1,000,000 individuals per square meter (USGS, 2007). They will colonize any stationary or slow moving hard surface, including mollusks such as native mollusks (MacIsaac, 1996). In one recent study, all live native mollusks collected from western Lake Erie were infested with Zebra Mussels (Schloesser & Nalepa, 1994). Colonization by the Zebra Mussel negatively impacts native mollusks by reducing their ability to move, feed and breed (USGS, 2007).

Sampling conducted in western Lake Erie in 1991 – two years after the introduction of the Zebra Mussel – found no live native mollusks in any of 17 sites where they had previously been found in relative abundance (Schloesser & Nalepa, 1994). This extirpation of native mollusks is not restricted to the Great Lakes, but has been observed throughout the Eastern United States. Rates of extinction of native mollusks have increased more than 10-fold in habitats where the Zebra Mussel has been introduced (Ricciardi et al., 1998). New populations of native mollusks will continue to come under threat as the Zebra Mussel spreads further across the United States.

Loss of the native mollusks is expected to alter ecosystems by changing particle dynamics (Strayer & Smith, 1996) and nutrient cycling (Nalepa, Gardner, & Malczyk, 1991). Commercial shellfisheries, who sell up to $40 million dollars annually of mussel shells to the Japanese pearl industry, will also suffer major economic losses because Zebra Mussel shells are not a suitable replacement (Ricciardi et al., 1998).

Solutions & Indicators

The Great Lakes Regional Collaboration (2005) identifies four primary factors that have led to the extreme levels of invasive species in the Great Lakes region:

1. Loose trade policies are failing to regulate the annual importation of millions of live organisms into the United States;
2. A lack of knowledge regarding best management practices and enforceable regulations, including those pertaining to ballast water from vessels, continues to leave the Great Lakes vulnerable to new invasion;
3. Efforts to respond to aquatic invasive species are disjointedly managed by more than 20 federal agencies and multiple states;
4. Individuals, from the pet trade industry to agriculture to recreational boaters, do not understand their role in stopping the spread of invasive species.

HR 500 offers several solutions to mitigate the problems of invasive species:

Solution 1: Restrict the trade of live aquatic organisms into the United States by mandating screening and approval by appropriate Federal agencies.

Indicator: To monitor the success of this initiative, the Aquatic Invasive Species Task Force, charged with reviewing the Federal agencies' screening and approval guidelines, will compile reported information from the Federal agencies concerning the number of species approved that became invasive, and the number of species introduced without prior approval. These two indicators will show how effective and how thoroughly applied the screening process is. However, it may be difficult to collect the needed information from the many agencies involved.

Solution 2: The bill requires vessels to maintain management plans designed to minimize introductions of aquatic invasives and to comply with ballast water performance standards promulgated by the Secretary of Homeland Security. This would require ships to be retrofitted with better ballast water technology as well as the development of new technologies (*Appendix A*).

Indicator: To monitor the success of this solution, the Department of Homeland Security may organize random inspections to determine what proportion of vessels are in compliance. However, thousands of boats use the Great Lakes each year, and it may be difficult to ensure that they are all included in the random sampling.

Solution 3: HR 500 authorizes funding for required Federal research to increase our understanding of best management practices to prevent, detect, and eradicate aquatic invasive species. H.R .500 would require the development of model state and regional aquatic invasive species response plans, as well as a coordinated Federal response plan.

Indicator: An indicator for the success of this solution would be the number of states that adopt the proposed plans. Unfortunately, the success of the plans cannot be monitored until an invasive species is introduced, at which point the success of this action could be gauged by the ability of the plans to control the rate of invasive species spread (acres/year, dollars of damage done, etc).

Solution 4: HR 500 calls for the Aquatic Invasive Species Task Force to develop and implement outreach and education to all vessel owners on the Great Lakes.

Indicator: The Task Force must periodically assess these programs with surveys to determine what proportion of boaters has knowledge of aquatic invasive species and exposure to the educational programs (HR 500, 2009). Monitoring will require a large sample pool to determine whether the information is reaching the boaters.

These strategies would help prevent the accidental and intentional introduction of harmful exotic species. Environmental and economic assessment will advance the argument that investments made now to prevent future introductions will be returned many times over in the preservation of natural ecosystems, diminished losses to agriculture and forestry, and lessened threats to public health (Pimental et al, 1999).

Toxic Substances

Problem Identification and Impacts

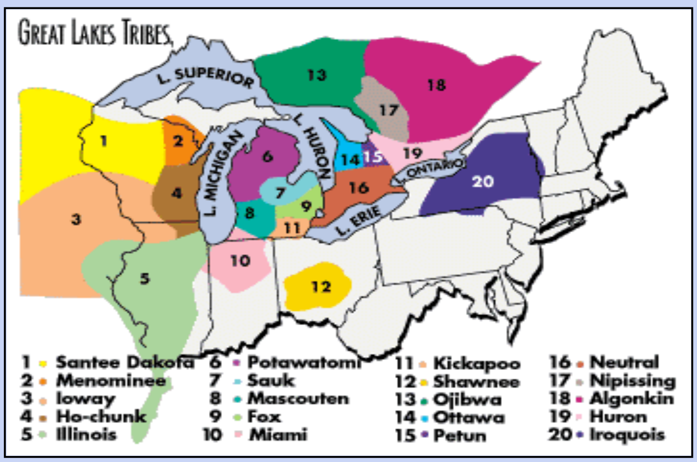
While discharges of toxic substances to the Great Lakes have declined over the last 20 years, previously emitted toxics still contaminate an estimated total of 75 million cubic meters of sediments at the 75 sites of greatest concern in the Great Lakes Region (GLRC, 2005). Approximately 1,000 substances of concern have been identified in the Great Lakes by the International Joint Commission. Of these, 11 have been classified as priority contaminants including polychlorinated biphenyls, dieldrin, DDT, 2,3,7,8-TCDD, 2,3,7,8-tetrachlorodibenzofuran, benzo[*a*]pyrene, mirex, hexachlorobenzene, toxaphene, alkylated lead, and mercury (Anderson et al., 1998). The effects of mercury on the Great Lakes system are among the most well documented.

Historically, mercury was discharged into the Great Lakes from industrial activity including paper manufacturing, chlor-alkali production, and mining (Nriagu, 1994; Rossmann, 1999). While most industrial dumping has ceased, direct dumping of mercury into the Great Lakes and anthropogenic deposition of mercury via atmospheric processes has increased the input of mercury into the lakes by a factor of 3 to 4 times since the pre-industrial era (Engstrom & Swain, 1997). The main sources of anthropogenic atmospheric mercury are coal and fuel combustion electric plants, iron and steel production plants, cement plants, and waste incinerators (Mohapatra, Nikolova, & Mitchell, 2007).

Once in the water column, mercury falls to the sediment surface by adsorption to fine organic and inorganic particles (Watras, Morrison, & Back, 1996). Mercury is then bio-accumulated up the food web, meaning that predators retain mercury from their prey. Mercury is a potent neurotoxin in wildlife, causing tissue lesions and degeneration of the central and peripheral nervous system, as well as kidney and liver failure (Borg, Wanntorp, Erne, & Hanko, 1966). Borg et al. have also linked mercury to lower reproductive rates in some bird species (1966).

Mercury enters the human body predominantly through consumption of contaminated fish (Anderson et al., 1998; Cole, Kearney, Sanin, Leblanc, & Weber, 2004; Peterson et al., 1994; Weis, 2004). Mercury poisoning can result in temporary or permanent loss of hearing, vision, sight, and taste, numbness, muscle weakness, and in severe cases, paralysis and death (Clifton II, 2007). It has also been linked with birth defects and cerebral palsy (Gilbertson, 2004).

Case Study: Fish Consumption and Mercury in Indian Tribes



According to the United States Environmental Protection Agency, 22 states have statewide mercury advisories, and 23 more have advisories for specific bodies of water (2006). Because fishing is essential to the traditions, social life and economic sustenance of many Indian tribes, the prevalence of elevated mercury levels in tribal members from the Great Lakes region is of specific concern (Dellinger, 2004; Peterson et al., 1994). As seen in the above illustration, there is a large presence of Tribal entities within the Great Lakes region. The widespread contaminants in Tribal waters have been found to be mercury, and the products of DDT, polychlorinated biphenyls, and dioxins. The occurrence of these toxins has negatively impacted the ability of some tribes to participate in traditional fishing customs.

Typical advisories warn children and women of childbearing age against eating more than one game fish per month (Lyderson, 2006). In tribal culture, fish dishes are served at ceremonies, funerals, fundraisers and other occasions. Most families have a freezer stocked year-round with fish, in bags labeled with the fish's size and lake of origin so they know its mercury risk (Lyderson, 2006). However, many tribal groups have reported that, based on current fish contamination levels, the quantity of preferred fish species that may be safely consumed is limited to 5% or less of the tribally designated allowable quantities (Institute of Science and Public Affairs, 2002).

Solutions & Indicators

HR 500 addresses toxics directly and indirectly through three different solutions:

Solution 1: For each of five years, $150 million would be authorized to remediate sediment contamination in "Areas of Concern" (as deemed by the Environmental Protection Agency).

Indicator: With sediment remediation projects, success is determined by how much of the sediment—measured in cubic meters—is successfully removed and the degree to which the risks to the ecology (Hartig, 1998) and human health are reduced (Ulrike Elisabeth Rolle-Kampczyk et al. 2006). The complexities inherent to each contaminated site require site specific criteria to determine success. Any assessment of success should include a measure of whether local goals, as defined by the public, are met. Any long-term rehabilitation of a contaminated area necessitates restoration of beneficial uses to the public (Hartig, 1998).

Solution 2: Authorize a mercury reduction program whereby the Great Lakes Program Office, housed in the Environmental Protection Agency, would provide grants to the Great Lakes States and Indian tribes in the region to reduce mercury levels (Great Lakes Act, 2009). HR 500 allocates $10 million per year over each of five years to provide grants to limit the quantity of mercury emitted.

Indicator: In the case of mercury reduction grants, success will be defined as achieving acceptable mercury levels in fish tissue. The amount of toxic methylmercury—the form of mercury that bioaccumulates—that can be safely ingested without being a health hazard (i.e. the reference dose) is a function of 1) the body weight of an individual, 2) the rate of consumption and 3) the amount of the contaminant found within the tissues of fish (California Regional, 2006; see Caste Study: Fish Consumption and Mercury Levels in Tribal Members).

Solution 3: HR 500 mandates that several Federal agencies—the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, and the U.S. Fish and Wildlife Service—create and implement water quality indicators and monitoring in collaboration with Canada. At a minimum, these indicators must include measures of toxic substances that have accumulated in the Great Lakes (Great Lakes Act 2009). It should be noted that, while the bill states that that new efforts are necessary to collaborate with Canada to address environmental problems in the Great Lakes, it does not specifically require this of U.S. federal agencies except for this provision.

Indicator: The Bill does not indicate as to what those environmental indicators would look like; however, minimally, "measures of toxic pollutants that have accumulated in the Great Lakes for a substantial period of time, as determined by the Program Office" (Great Lakes Act, 2009).

Wastewater Discharges

Problem Identification and Impacts

The Great Lakes Collaboration Implementation Act identifies wastewaters, runoff and treatment outflow from urban and agricultural areas as a significant threat to the Great Lakes ecosystem. Partially treated sewage contains human waste, oxygen-consuming materials, suspended solids, disease-causing pathogens, excess nutrients, polychlorinated biphenyls, and elevated levels of heavy metals including cadmium, lead, mercury, silver and zinc (Great Lakes Commission, 2009; Sierra Legal Defense Fund, 2006). These pollutants present a public health risk by contaminating public beaches, drinking water, and fish populations. Unsafe concentrations of these toxins contribute to biodiversity loss in the Great Lakes ecosystems (Sierra Legal Defense Fund, 2006; Environmental Protection Agency, 2008).

Sixty five percent of the nation's combined sewer overflows are in the Great Lakes Region (Great Lakes Commission, 2009). The wastewater infrastructure of the states surrounding the Great Lakes is not adequately equipped for handling waste generated by the region's growing population and increasing urbanization. The cities surrounding the lakes have outdated collection and treatment systems that are often overwhelmed during wet weather events and peak inflow hours (Great Lakes Commission, 2009). Consequently, during surges in wastewater inflow, raw sewage can bypass the treatment process or can be blended with treated water; both of these actions result in combined sewer overflows and subsequent pollution of the lakes.

The Great Lakes Basin contains an estimated 43% of the combined sewer systems operating in the country (Environmental Integrity Project, 2005). Wegener (2001) identified a 69% increase in runoff 1937 and 1995 due to increasing urbanization and associated impermeable surfaces. This increase in load has resulted in increased stress on sewer systems in the Great Lakes region. For example, a single storm in May of 2000 caused 1 billion gallons of raw sewage to be released to Lake Michigan and its tributaries (Whitman, 2000).

Also detected in wastewater treatment effluent in the Great Lakes region are pharmaceuticals, including caffeine and acetaminophen (Wilcox, Bahr, Hedman, Hemming, Barman, & Bradbury, 2009), and estrogen mimicking chemicals such as Bisphenol A. Bisphenol A has been shown to reduce fertilization success, egg numbers, mating behavior, and spawning time in aquatic organisms (Segner, Caroll, Fenske, Janssen, Mack, et al., 2003).

Agricultural runoff is another significant contributor of contaminants to the Great Lakes. Wolter, Johnson, and Niemi (2006) have estimated that approximately 33% of the land in the Great Lakes basin is cultivated. Excessive application of phosphorus fertilizer can lead to eutrophication, resulting in algal blooms (Environmental Protection Agency, 2006).

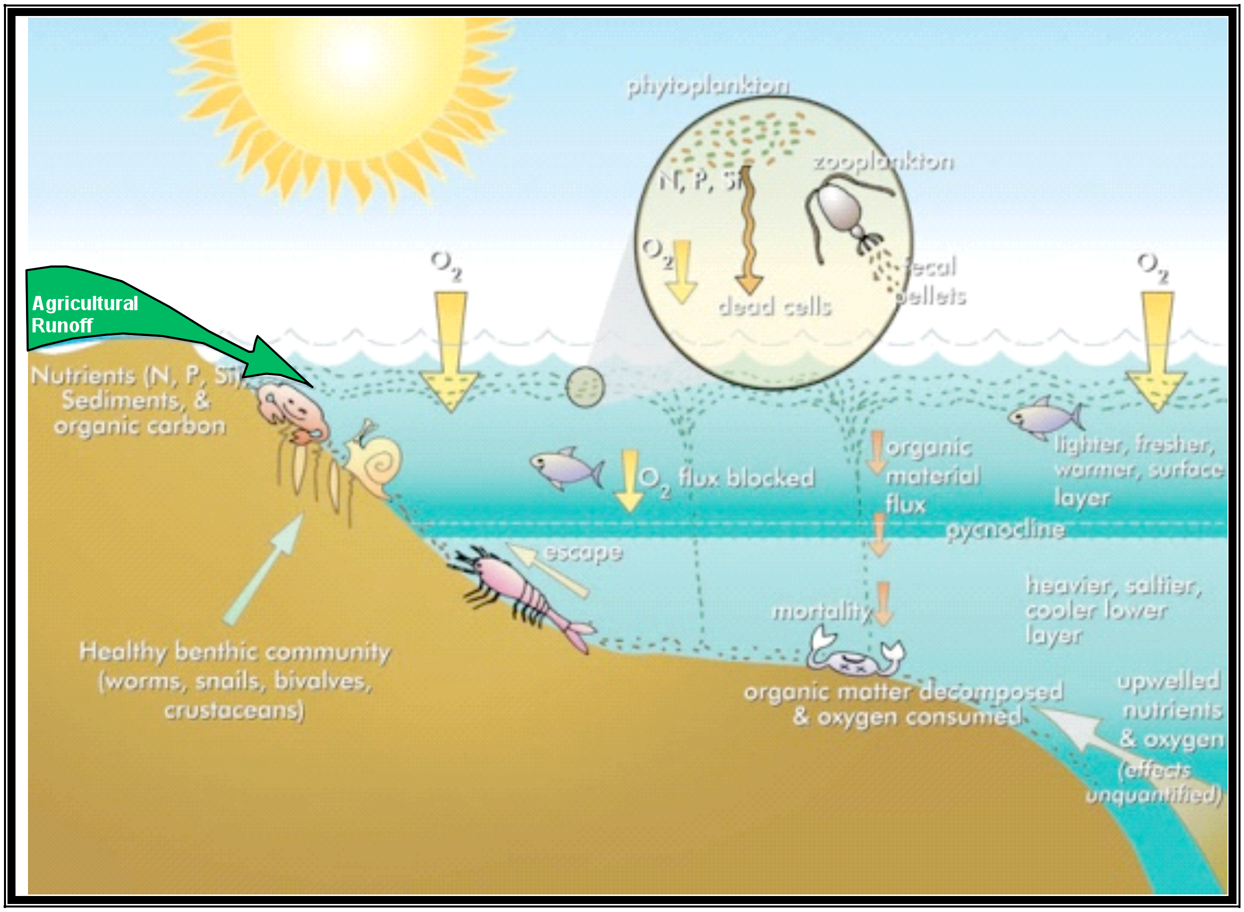


Figure 3 Agricultural runoff contributes high levels of nutrients to the water, leading to algal blooms. As the mat of photosynthetic algae grows thicker, the algae at the surface prevents light from reaching those underneath. Massive numbers of the light deprived organisms die and fall to the bottom of the lake where they decompose. Decomposition consumes oxygen in bottom waters, leading to conditions of hypoxia (oxygen deficiency). Oxygen levels can fall so low that the water is unable to sustain aquatic life and forms a dead zone. A dead zone forms in Lake Erie each summer, sometimes covering up to 6300 square miles. (Image modified from U.S. Environmental Protection Agency, http://www.epa.gov/msbasin/images/eutro_550w.jpg.)

Solutions & Indicators

HR 500 attempts to address the problem of wastewater overflows in two ways:

Solution 1: First, the Bill provides for technical assistance to small municipalities for improvements for their wastewater infrastructure. To help finance this, HR 500 would authorize $75 million for each of five years.

Solution 2: HR 500 authorizes an additional $20 billion over five years in water pollution control revolving loans for small water treatment systems.

Indicator: The overarching goal of the wastewater discharge program is zero under-treated waste discharged into the Great Lakes, or related water systems. While HR 500 does not explicitly address the monitoring methods to be used to evaluate the progress made in water quality, we assume that traditional drinking and wastewater treatment analyses will suffice as indicators. For example, the EPA has established a health goal for zero total coliforms in drinking water. Water systems that confirm the presence of coliforms in more than five percent of the samples collected each month will fail to meet the total coliform standard. If fecal coliform is present in water (as measured in colony forming units per 100 ml of water), this could be a direct indication of the malfunctioning treatment technologies. Therefore, systems may need to repair the disinfection/filtration equipment, flush or upgrade the distribution network, and develop more protection programs to prevent contamination (Dreelin, 2008).

Wastewater treatment facilities in the Great Lakes have been monitored for total coliform levels according to EPA standards (Dreelin, 2008). In addition to this method of testing, researchers have applied analytical techniques including spectrophotometry, gas chromatography and mass spectrometry, to wastewater discharges. These methods can be applied in the Great Lakes Region for monitoring of both wastewater and toxic pollutants.

Wetland Degradation

Problem Identification and Impacts

Wetlands store precipitation and surface water and then slowly release the stored water into adjacent surface water bodies, ground water, and the atmosphere (Turner and Gannon, 1995). This process slows the waters' momentum and erosive potential, reduces flood heights, and allows for groundwater recharge, which contributes to base flow to surface water systems during dry periods (Environmental Protection Agency, 2001). Wetlands dominated by precipitation generally consist of clays and peat that retain water and are low in nutrients and pH. Their ability to retain water provides flood control and allows a longer residence time for filtering pollutants. Wetlands fed mostly by groundwater are nutrient rich providing for a wide range of subsurface species that aid in water filtration.

Biogeochemical cycling and storage are functions performed by wetlands that remove contaminants from the water system. Bacteria eliminate nitrogen through aerobic and anaerobic reactions, referred to as oxidation and reduction. Phosphorus removal occurs in several ways: by the activity of plants and soil microbes, by adsorption to metal oxides found in the clay rich soils, or by absorption to sediment particles (Turner and Gannon, 1995). Heavy metals, such as mercury, are removed by settlement via ionic attraction to clay particles. The contaminants, once converted, may become buried or released into the atmosphere.

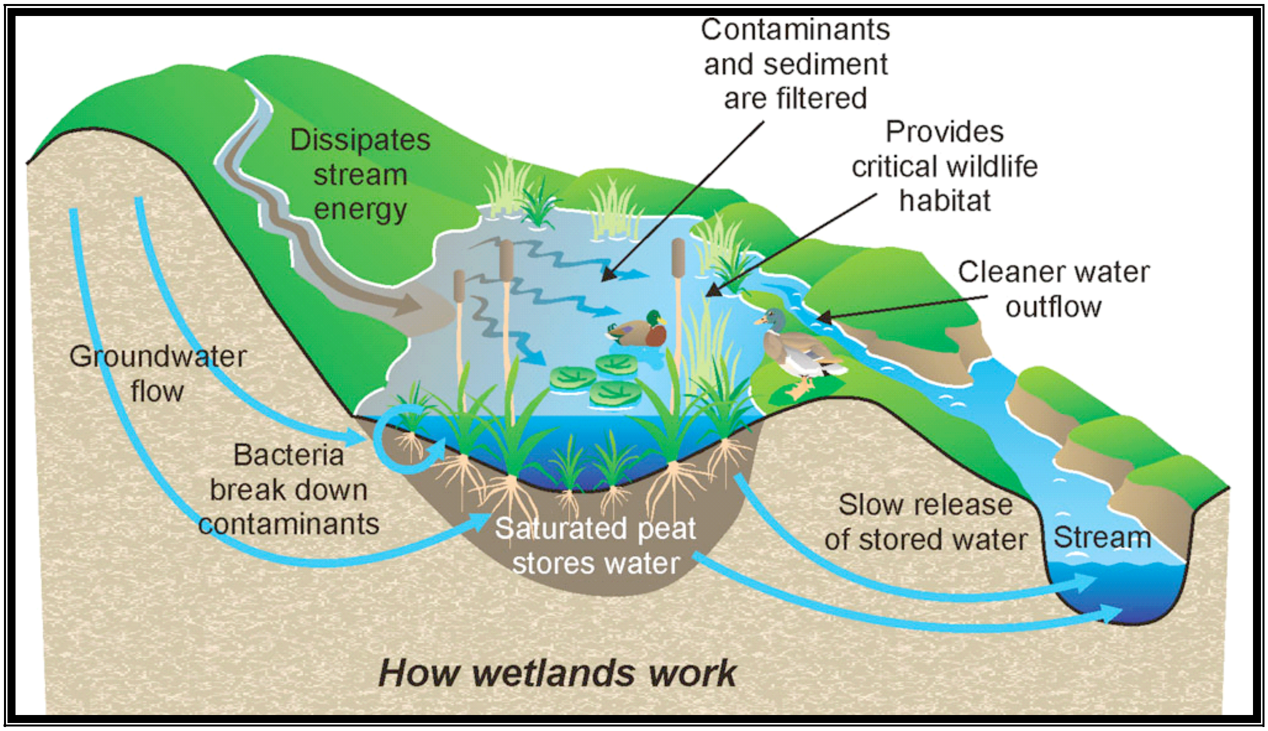


Figure 4: Wetlands provide a number of ecosystem services to the Great Lakes environment. Incoming surface and groundwater is slowed, reducing its erosive potential. Sediment and contaminants are filtered by aquatic plants, and bacteria in the wetland soil breakdown contaminants. The wetland soil stores water that might otherwise result in a flood. The water emerges cleaner, improving the quality of the lakes. (Image source: Natural Resources Canada, http://geoscape.nrcan.gc.ca/h2o/bowen/factory_e.php.)

An estimated 60% of wetlands in the Great Lakes Region have been lost to development, massively decreasing the availability of the associated ecosystem services in the region. While the Great Lakes region still hosts millions of acres of wetlands, urban development threatens the health of these remaining areas through filling and dredging, shoreline alteration and armoring, waste dumping and effluent contamination, and upstream water control. Agricultural operations have contributed to nutrient loading and increased turbidity. The loss of wetlands and wetland services warrants specific concern in areas of climate regulation, water quality and quantity, biological diversity, and as a sink for carbon and heavy metals.

The U.S. Fish and Wildlife Service has identified 130 endangered or rare plant and animal species within the Great Lakes basin (2005). Wetlands also provide habitat for a plethora of other flora, migratory birds, amphibians, reptiles, insects and predators. Wetlands are able to sustain a diverse range of species due to the diversity of habitats and the presence of shallow waters. The interaction of these species assists in the maintenance of the wetland ecological functions. For example, aquatic plant life can derive benefits from the nutrient-rich environment, and this energy converted by the plants is then passed on to higher trophic levels such as fish, waterfowl, and other wildlife and humans (Environmental Protection Agency, 2001).

Solutions & Indicators

In order to preserve the remaining wetlands and the ecosystem services they supply, H.R. 500 makes three stipulations:

Solution 1: H.R. 500 seeks to decrease wetland destruction from pollution and development by redefining the jurisdiction of the Federal Clean Water Act by replacing the phrase "navigable waters" with "waters of the United States." This change would allow for much greater control by the federal government over wetlands, which may be seasonally extant and therefore not considered "navigable" (Lane, 2005).

Indicator: Success in the application of the protections of the Clean Water Act to the Great Lakes wetlands may be measured in several ways. One may look at the reduction in the number of acres of wetlands filled by development against a baseline year. The program is successful if the number of wetland acres filled per year declines. One may also look at the percentage of permits being granted for wetlands to be filled in as a measure of the success of the program. A low percentage of permit approval suggests that wetlands are being protected by the managing agency.

Solution 2: H.R. 500 would authorize $105 million for research grants through the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, and for projects undertaken by the Great Lakes Science Center. H.R. 500 implicitly grants great discretion to these entities to determine what research is undertaken and what is done with the results. However, proposed funding is intended to improve data quality and enhance understanding of the Great Lakes ecosystem functions, their threats, and their needs.

Indicator: Restoration success may be measured by the total number of acres of wetlands restored, or by the sum of the ecological services provided by those wetlands. There are two accepted and widely used ways to determine if a wetland has been successfully restored: functional success, and compliance success. Functional success is defined as the restoration of sustainable ecological functions (i.e. processing nutrients, harboring wildlife, and storing floodwater) of the wetland being restored (Quammen, 1986). Compliance success is a quantitative success determination that compares the restored wetland to a predetermined set of parameters.

Solution 3: H.R. 500 would authorize $50 million to the Secretary of Commerce to restore wetland areas, with full discretion granted to the Secretary of Commerce to fulfill this provision. These proposed authorizations would be intended to not only slow the destruction of wetlands, as in the change in the definition of "navigable waters", but to actually increase the amount of wetlands on the Great Lakes coasts. Commonly used metrics in determining success include surveys of vegetation, soils, and hydrology (Kentula, 2000).

Indicator: Vegetation may be assessed by surveys of vegetation in the restored wetlands and comparison to a native, undisturbed wetland nearby. Similarly, organic and nutrient contents of soils may be compared to other reference wetlands. Lastly, hydrologic functions, such as water holding time, may be measured to indicate if ecosystem function has been restored. Holding time is a measure of how long it takes water to move through a wetland, and is typically measured by placing tracer chemicals in the influent to a wetland and measuring how long it takes for those chemicals to appear in the wetland effluent. Holding time is an important function because other ecosystem services such as nutrient, sediment, and contaminant removal are functions of the holding time (Kröger et al., 2009).

With the four problems identified and potential solutions selected, implementation of these solutions may still encounter resistance due to scientific uncertainty or disputes between stakeholders. In terms of the science and technology used to address environmental problems, much of the information behind these solutions is inconclusive or barely established. Uncertainty will reign until the technology has been widely implemented and tested. Unfortunately many of these technologies are new and going through a testing phase may last years which can oftentimes be impractical. Therefore HR 500 must find technological and scientific solutions that offer the greatest likelihood of success while also being readily implemented. In terms of stakeholder disputes, most of the disagreement hinges on cost, and despite scientific findings, stakeholders will push for outcomes based on their personal agendas. For these disputes final consensus will likely be based on the cost-effectiveness of the program.

Uncertainties or Controversies Concerning Solutions

Sediment Remediation

The ultimate goal of sediment remediation is to reduce the risks posed by sediment-bound contaminants to protect the health of humans and the environment and to restore the damaged ecosystem (Wenning et al. 2006). The optimal means of sediment remediation for heavy metal contamination is highly site-specific and depends on local ecological conditions. The EPA has supported a combination of remediation approaches – dredging, capping, and monitored natural recovery (MNR) is usually appropriate (EPA, 2005).

The controversy centers on the potential ecosystem and habitat disruption caused by dredging and excavation of contaminated sediments, in comparison to the relatively questionable practice of either capping sediments or monitoring polluted sites with no action (e.g. MNR).

Dredging is considered the most invasive form of remediation. It has the potential to alter geochemical conditions and increase bioavailability of many toxins. For instance, more toxic species can be formed from relatively inert metals when sediments are mixed and oxidized, including hexavalent chromium and methylmercury, two chemicals that can be more easily taken up and bioaccumulated in aquatic organisms (Wenning et al. 2006). Other negative impacts of dredging include habitat destruction, redistribution of contaminants, increased bioaccumulation, and new or exacerbated exposure pathways (Wenning et al. 2006). The possibility of creating one of these adverse outcomes has put scientists and stakeholders at odds. However, the EPA argues that dredging allows contaminants to be removed and disposed of in a controlled setting, and other supporters of dredging argue that it provides more flexibility in the future use of the water body (i.e. sediment does not have to be carefully left undisturbed) (US EPA 2005).

More passive approaches such as capping and MNR are sometimes advocated as less intrusive alternatives. MNR, meaning either "no action" or the application of thin layer of clean sediment to seal off the contaminated layer, requires monitoring to ensure that the "acceptable" level of risk is maintained and does not worsen. No costly infrastructure is needed and the ecosystem is left undisturbed, but questions remain about the flux of contaminants to the water column without engineered containments of sediments. This technique is quite slow in reducing what many see as urgent risks, in comparison to more active remedies (EPA, 2005).

Capping, an "in-between" approach, is the use of layers of clean sediment, such a sand or gravel, to physically isolate the contaminated layer, both from burrowing organisms and from flux to the water. It also prevents erosion of contaminated sediments with water movement. Opponents contend that although this is a quick fix, addressing the root problem and incurring the short term economic and ecological costs of excavation, rather than simply covering the contamination and leaving it with the possibility of being exposed or disturbed, is preferable. Dredging would remove the contaminant and more readily isolate it from biotic contact (EPA, 2005).

Many uncertainties about post-remediation contaminant behavior and the ways in which mercury can affect the ecosystem in the long term persist, particularly if source control is unsuccessful. Efforts at remediation will of course have little effect if new deposition cannot be controlled. Debate continues about whether active remediation approaches may actually be more harmful to the environment than the (relatively inert) presence of the contaminant itself; risk-assessments must be undertaken for the particular site.

Case Study: Dredging in Manistique River, Michigan

The Manistique River is an example of a remediation program that did not meet expected costs or results. The Manistique River is located in Michigan's Upper Peninsula and discharges into Lake Michigan. Historically, the river has been used by industry to dump waste products. Some of the industries that have used the river include sawmills, small industries, a paper mill, small industries, al waste water treatment plant (US EPA 2009). In 1987 a remedial action plan was established and in 1995 the EPA began annual dredging of the site (US EPA 2009).

Figure **5**: Manistique River, MI. This site was targeted for dredging to remove PCB contamination left over from historical waste dumping in the river

During the program the EPA released reports detailing the successes of the dredging method, but disputes soon began to surface stating that dredging did not fully resolve the problem and that the financial cost of the dredging could be high (Meers et al., 2003). Many believe that although dredging is capable of removing vast amounts of contamination, it still leaves a significant amount of contamination in the soil. "No existing dredge type is capable of dredging a thin surface layer of contaminated material without leaving behind a portion of that layer and/or mixing a portion of the surface layer with underlying clean sediment" (Palermo, 1991). The EPA went forward with the project and set a goal of 10 ppm for toxins found at every level of the sediment. The project was budgeted to be $15 million dollars with funds lasting through 1997. In 1999 the EPA took five core samples from Manistique River. PCB concentration averaged 48 ppm, well above their 10 ppm objective. In response the EPA pushed the project deadline to the end of 2000 with a new budget of $42 million (DEQ, 2000). The dredging solution for Manistique River was costly and not as effective and planned.

Ballast Water Management

Ballast water, the main vehicle for invasive species import, was largely overlooked in the Clean Water Act of 1972, and went unregulated throughout most of the U.S. until recently. Policy debate over ballast water management is largely concerned with how ballast water treatment systems can meet increasingly stringent regulations. The prevailing question is this: can this threat be realistically addressed, given the cost burden to the shipping industry and the lack of proven technology to eradicate all organisms from ballast water? Treating ballast water tends to be an all-or-nothing conundrum; missing just a few organisms during treatment can mean their species' eventual rampant spread throughout the ecosystem.

Currently, a combination of filtration, chemical treatment, and UV treatment cannot completely eradicate all organisms from on-board ballast water. Large organisms can be removed through filtration and secondary UV treatment can reduce the presence of microorganisms below detectable levels. UV radiation is commonly considered one of the most viable secondary treatments, believed to kill or inactivate viruses, bacteria, protozoa, fungi, molds, yeasts, and algae (ICMES 2000). However, dissenting evidence suggests that these organisms may survive at extremely low levels and reappear within 18 hours, revealing that sufficient population levels needed to reproduce and multiply can persist through treatment (Waite et al. 2003).

Waite et al's 2003 study showed that physical screening of water at 50 um removed most zooplankton and some microphytoplankton. UV treatment was found to be largely ineffective in inactivating microorganisms. Only screening proved effective in removing most organisms, especially zooplankton and invertebrate larvae. Filtration was found to be most effective when used in concert with other on-board treatment mechanisms, which could greatly decrease the abundance of surviving bacteria and viruses. Phytoplankton were not affected by filtration, however, and UV treatment of phytoplankton would not be a very useful or efficient process. The study's findings suggest that a UV dose sufficient to permanently inactivate all organisms in the tank would have to be excessively high (Waite et al. 2003).

Shipboard treatment, though vastly more reliable at removing invasive species, would be at least ten times more costly and much more time-consuming than traditional ballast water exchange, requiring each vessel to be refitted with new technology. Many argue it is impractical for the large volume of water that needs to be treated, which increases ballasting time and can interfere with normal ship operations (ICMES 2000).

There is also extensive disagreement over Zebra Mussel eradication. The most realistic technological answer to their current infestation is injection of potassium chloride (KCl), which has been used with success in Virginia's Millbrook Quarry. The Virginia Department of Game and Inland Fisheries (2007) reported that the KCl used to kill Zebra Mussels is completely safe for humans and the environment, at 100 mg/L (allowable levels in drinking water are 250 mg/L), especially since it is also widely used in home water softeners. The treatment was successful in eradicating the Zebra Mussel infestation in the quarry.

It has been argued, however, that the quarry scenario is not transferrable to the Great Lakes. Since it is a small scale man-made environment, most of the wildlife has been imported and there were no sensitive freshwater molluscan species that could have been harmed by the treatment. A report by the US Fish and Wildlife Service argued that the treatment would likely be ineffective in the vast, interconnected waterways of the Great Lakes. The hydrology of Millbrook Quarry is quite simple in comparison; the quarry is small with no surface flow and limited groundwater attachment to adjacent water bodies (US Fish and Wildlife Service 2007).

Wastewater Treatment

Wastewater treatment systems are outdated and inefficient at removing pollutant from sewage and stormwater before it enters river, stream, and ocean ecosystems. For this reason, H.R. 500 allocates funding to reduce the number of combined sewer overflow (CSO) events in the Great Lakes region. The controversy stems from the fact that there are many different technologies that aim to reduce CSO events, and a lack of consensus about which technology is best. The lack of documented information concerning past attempts at various scientific and technological approaches means that "..it could not be determined whether each project was a wise investment of taxpayer dollars" ("Wastewater Management," 2002). Without knowledge of which scientific approach to pollution removal is most successful environmentally and fiscally, there will be disagreement surrounding wastewater treatment system upgrades.

The goal of any system upgrade would be to reduce the amount of water that reaches wastewater treatment plants that have combined sewer systems so that the flow stays within system capacity, and does not require operators to discharge untreated or partially treated sewage. There are a variety of ways to achieve this goal; municipalities must first decide to alter treatment, storage, or collection of wastewater. The various technologies appropriate for improving treatment, increasing storage, or retrofitting collection systems are built around different scientific approaches that are each potentially controversial. For instance, adding large retention basins that partially treat and hold water in large underground storage tanks requires an invasive construction process that commonly results in other types of environmental damage (Delany, 2008). On the other hand, retention basins are proven to reduce the amount of fecal coliform entering water systems (Delany, 2008). The use of chlorine as a disinfectant in water is very effective and commonly used, but is contested, as there are possible toxic side effects and safety concerns regarding handling ("Technology Fact Sheet," 2008). Issues like these open debate over which systems upgrades are most appropriate.

H.R. 500 only allocates funding to reduce CSO events, so there will be advocates for many different scientific and technological approaches. This debate surfaced in Dearborn, MI where citizens voiced discontent with the choice to add retention basins to the sewer system, as opposed to putting in an entirely new sewer system that separates wastewater and stormwater collection altogether (Delany, 2008). Ultimately, limited consensus was reached based on the cost of the two different approaches (the retention basin system was chosen), without much consideration for environmental health (Delany, 2008). Cities surrounding the Great Lakes will make similar decisions if the bill is passed, and there is no doubt that controversy will ensue.

Wetlands

While the benefits that wetlands provide to any water system are well understood and largely without controversy, the construction of artificial and the enhancement of natural wetlands does raise some questions. In terms of their biological functions, artificially constructed wetlands serve largely in the same capacity as those occurring naturally. However, in terms of size and capacity, these wetlands are typically smaller and cannot absorb flow at the same rate as larger natural wetlands. Surges in water flow can temporarily reduce their effectiveness. There is yet to be a consensus on the optimal design of artificial wetlands, and data on their long term effectiveness is scarce (DuPoldt et al.).

Implementation of remediation programs in response to Great Lakes environmental problems will likely meet opposition from the scientific community and from a variety of stakeholders. Scientists will highlight the uncertainties of a particular program while many stakeholders will be interested in how cost-effective the environmental solution is. In order to allay uncertainties and ensure the cost effectiveness of implemented programs, HR 500 will emphasize monitoring procedures for programs.

Monitoring

For implementing any ecological protection and restoration effort, monitoring is of the utmost importance. The uncertainties and complexities of ecosystems make continuous information collection essential to ensure that efforts are having the desired effects, and that they are sufficient in scope. For the Great Lakes, such efforts are already under way, lead by the National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Laboratory and the Environmental Protection Agency (EPA). The Great Lakes Collaboration Implementation Act, also known as HR 500, will add new stipulations to preserve, protect, restore, and monitor this invaluable ecosystem, and therefore methods of monitoring and evaluation, both scientific and administrative, will be employed.

Technology and Science of Monitoring

HR 500 will employ a variety of technologies to evaluate the success of remediation programs. The sophistication of the tools used to monitor success can vary greatly in both costs and sensitivity. Three highly sensitive monitoring techniques likely to be employed by HR 500 include spectrophotometry, gas chromatography and mass Spectrometry. These techniques can ascertain miniscule variations in wastewater, making them valuable in determine the presence of pollutants. Spectrophotometry has been used with success to evaluate contamination levels in urban wastewater. Urban wastewater consists of a mixture of organic and mineral pollutants that vary in size. When analyzed these particles display large differences in optical properties (Azema et al. 2002). Most of these organic particles and certain soluble minerals found in wastewater absorb near the UV region and therefore can be detected using a spectrophotometer (Vaillant et al. 2002).

Gas Chromatography and Mass Spectrometry have also been successful in the field. Both techniques were pioneered by the USGS, field blanks and method blanks allow for the detection of low-levels of contamination. These samples are then tested for a variety of sewage indicators including pesticides, caffeine, alkylphenols, and several semi-volatile organic compounds. Overall, this method has successfully detected over 46 anthropogenically introduced compounds (Brown et al. 1999).

Case Study: Green Bay Mass Balance Study

Setting effective but reasonable goals presents a challenge for any remediation or pollution abatement program. To address this, the Environmental Protection Agency undertook several mass balance studies in different areas of the Great Lakes, including Green Bay in Wisconsin.

Scientists from multiple state and federal agencies pooled their resources for this monitoring project. Pollution specialists tracked the movements of pollutants, from nutrients to toxins, through Green Bay and used the data they collected to create computer models. These can be used in the future to help predict pollution movements and outcomes, and inform new goals and strategies for pollution abatement.

However, it has been almost two decades since the undertaking of the Green Bay Mass Balance study. What new variables have emerged in the 21st century?

With the implementation of HR 500, such studies would have further support and resources. Designed to support and engender such collaborative projects, the bill would establish an integrated system to improve coastal monitoring, and support research and collaboration through the Interagency Task Force and the EPA.

Supporting monitoring projects such as this helps ensure that pollution reduction resources are deployed efficiently and effectively, and that they improve the region’s economic and environmental wellbeing.

Best Management Practice Improvements

HR 500 allocates hundreds of millions of dollars to research concerning invasive species and wetlands. However, this is a difficult solution to gauge. The best indicator for research would be the number of contributions yielded by the projects that improve best management practices. However, judging the effectiveness of these practices would be somewhat subjective.

Research Collection and Analysis Methods

The monitoring systems under the abovementioned Great Lakes Environmental Research Laboratory and used by the EPA are already well established, and information collection is ongoing. The two primary methods of detecting invasive species are highly versatile remote sensors (Goetz et al, 2008) and field research (Lee et al, 2008). For invasive species, the most effective monitoring is on-site observation. For wastewater and toxics, the above mentioned spectrophotometry and mass spectronomy are the best methods. For wetlands, there are a variety of indicators that can be observed, but are not currently catalogued in any coherent way. HR 500 also mandates the creation of an Integrated Oceanic and Coastal Observing System, an effort that will contribute greatly to the standardization of data collection. Not only will it expand the range of data collected, but it will ensure that the same methods and variables are used for testing by the many different agencies who currently study the Great Lakes.

Conclusion

HR 500 addresses the overarching concerns within the aquatic environment, including the persistence of invasive species, the control of toxic pollutants (e.g. mercury), wastewater pollution, and wetland destruction. The bill presents a pathway of solutions towards ecological restoration within the Great Lakes. This vast surface freshwater system, while supporting an array of biota and providing nonquantifiable ecosystem services, is also responsible for the health and well being of over 35 million people and supports a multitude of industries that are both significant regionally and nationally. While coordinating the interests of multiple stakeholders, HR 500 provides opportunities for holistic efforts towards a common goal.

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Glossary

Authorization
This is the amount of money which, according to the bill, is allowed to be spent by Congress to support the programs elaborated in the bill. However, Congress can only allocate this money through the budget process. The final allocations are often mush less than the bills authorizations.

Ballast water
This is the water which ships take into tanks in their holds to help keep them stabilized. Because the ships fill their tanks on one place and empty and refill them in another, ballast water can be a vector for invasive species introductions.

Combined sewer overflow
A combined sewer overflow occurs when a a heavy rain causes a combined storm- and wastewater treatment system of a municipality to exceed capacity. As a result, a mixture of untreated wastewater and stormwater will be released into a water body.

Dredging
This involves using hydraulic hoses, backhoes, or other machinery to remove sediment from the bottom of a water body. It is a commonly used technique for remediation or to deepen a water body to facilitate shipping.

Environmental Protection Agency (EPA)
This is the Federal organization which is highly involved in many aspects of Great Lakes research, restoration, and pollution mitigation. The EPA implements many pieces of national legislation, including the Clean Water Act, is the primary agency that undertakes monitoring of the Great Lakes, and disburses research grants, among other activities.

Eutrophication
This occurs when nutrient excesses cause unusually intense blooms of algae in a water body. When the algal bloom dies, the decomposition uses up the dissolved oxygen in the water, which can create a "dead zone," or a place where the oxygen is too low to support life.

Fish and Wildlife Service
This is an agency under the Department of the Interior that undertakes monitoring and enforcement of wildlife laws in the Great Lakes region, including the Endangered Species Act.

Great Lakes region

This is the region that includes the Great Lakes and all contiguous US states, such as New York, Pennsylvania, Ohio, Michigan, Indiana, Illinois, Wisonsin, and Minnesota and Canadian Provinces, including Ontario, Quebec, and Manitoba.

Great Lakes Regional Collaboration (GLRC)

This group formed as part of a US executive order to bring together diverse stakeholders for the purpose of establishing a strategy for addressing the problems faced by the Great Lakes region. It continues to compile information concerning the progress of Great Lakes restoration efforts, and issues reports periodically.

Invasive species

An invasive species is defined as any non-native species that is likely to cause harm to the economy, the environment, or the human health of an particular ecosystem.

Methylmercury

This compound is the most bioavailable form of the neurotoxin mercury, and therefore highly dangerous to human health. It is generated by microbes in sediment when they process mercury released from industrial processes, and it bioaccumulates to fish that are consumed by humans. Content of methylmercury in fish tissue is a valuable indicator for ecosystem health.

Non-point source pollution

This occurs in the form of runoff from areas where pollutants that are spread out over a large space. This may be in the form of agricultural runoff containing fertilizers and pesticides that were applied over a large farm field, or urban runoff from city streets.

National Oceanic and Atmospheric Administration (NOAA)

This Federal agency operates the Great Lakes Environmental Research Laboratory, which undertakes monitoring and research activities throughout the region. NOAA also disburses research grants for studies of the Great Lakes.

Remediation

Regarding ecosystems, remediation generally refers to restoration to a previous level of ecological health, usually experienced prior to a human disturbance.

Sediment

This substance is the collection of silt and other organic and non-organic particles that collect on the bottoms of water bodies. Sediment is often a medium of contamination though heavy metals, PCBs, or other heavy pollutants those settle out of the water.

Toxic pollutant
This refers to any substance, usually anthropogenic, that has been found to cause significant harm to human or ecological health when released into an ecosystem.

Waste water
This refers to the effluent containing various forms of human wastes which come from the use of water for domestic or industrial purposes. The most common form of waste water is sewage or stormwater, which can be ecologically problematic if it enters the ecosystem untreated (see combined sewer overflow).

Wetland
This ecosystem is defined by soil saturation, though not necessarily inundation, by water. The characteristics of wetlands can vary widely, but all are defined by plant and animal species that are adapted to the presence of water during a large portion of the year.

Zebra Mussel
This highly invasive species was introduced from the Caspian Sea to the Great Lakes through ballast water discharge. Because if its small size, high fecundity, and lack of predators, it has spread rapidly throughout the region and causes hundreds of millions of dollars of damage each year.

Appendix:

Technology	Description	Impacts, Pros and Cons
Dredging (contaminated sediment remediation)	Contaminated sediment (usually mercury contamination) is dredged, excavated and moved offsite where it can be isolated	Stirs up sediment and renders toxins bioavailable, can destroy habitat and ecosystem, but toxin can be easily removed, controlled, and isolated
Capping	Contaminated sediment at the bottom of a waterway is sealed off with sand, gravel, or other sedimentary material	Somewhat less intrusive than dredging, but the risk remains that sediment will erode or be reexposed. Capping does not fundamentally remediate the contamination problem, but leaves the potential risk in place
Chemical treatment of invasive species	Potassium chloride is injected into the water bodies to eradicate Zebra Mussels, which asphyxiates them.	Likely to harm native freshwater mollusk species as well, potential ecosystem disturbance and groundwater contamination. KCl itself is harmless, however, and commonly used in home water softeners. Additionally, concentrations in water would not exceed specified concentrations for fresh drinking water.
On-board ballast water filtration	Screens filter large organisms and many microorganisms to prevent their invasive spread in the water body during ballast water exchange	Filters often miss organisms smaller than 50 um, process may be impractical for large amounts of ballast water and limited time available for

		ballasting.
On-board ballast water UV treatment	UV treatment inactivates most organisms to prevent their release during ballast water exchange	UV is not environmentally harmful as chemical treatment would likely be; however, it has the potential to eliminate microorganisms to "non-detect levels" initially but still leave sufficient individuals to multiply rapidly again soon after. On-board ballast treatment is potentially quite costly and impractical.
The vertical treatment shaft	Brings together the combined sewer overflow system with storage and treatment capacity. Designed to provide skimming, settling, screening and disinfection for all flows beyond storage capacity.	Avoids short circuits of flow, and disinfection contact time. It requires economies of scale to become economically a feasible option.
Chlorination/disinfection	Treatment of wastewater to reduce the number of microorganisms in the water to be discharged back into the environment. It depends on the quality of the water being treated (cloudiness, pH, etc.)	Chlorination remains the most common form of wastewater disinfection in North America due to its low cost and long-term history of effectiveness. However, chlorination can generate chlorinated-organic compounds that may be carcinogenic and harmful to the environment.
Wetland Filter enhancement	Cleaner water, Ecosystems services. It's a natural process that filters' and purifies the water. Applied in places where wetlands exist/existed.	Provides ecosystem services and regenerates ground water. It's not purified drinkable water.

Catchment ponds	Water infiltrates and is purified by natural processes of filtration. It's applicable in urban areas to catch runoff and filter.	Filters contaminated can runoff, it's centralized mostly around storm events.
Rain catchment	Landscape and grey water uses. Catchment system that collects rainwater and stores it for later use. Offsets use of potable water effectively reducing consumption.	Creates new water supplies/limited to the amount of annual rainfall
Water reclamation	It's a mechanical, biological and chemical filtration method to remove human and industrial contaminants from water. 30% of pure water if primary treated, 70-80% pure water if secondary treated, drinkable water if tertiary treated	Applicable anywhere significant waste water amounts are generated by humans or industry. Clean water, variable levels of treatment depending on investment/expensive, require extensive infrastructure and monitoring, and requires a high degree of power