2021

Lake Erie Conservation:

Tackling Phosphorus Eutrophication

Division of Global Sustainable Development

University of Warwick

Lake Erie Conservation:

Tackling Phosphorus Eutrophication

Executive Summary

Located on the international border between Canada and The United States, Lake Erie is home to 1500 species, and supports millions of families on a transboundary level. The Great Lakes support over 30 million people, accounting for 10 percent of the US population and 30 percent of the Canadian population. In the last 100 years, Lake Erie has been subjected to eutrophication that is human induced as a result of anthropogenic and ecological pressures. Excessive phosphorus concentrations as a result of non-point agricultural run-off are a major contributing factor to the growth of Harmful Algae Blooms in Lake Erie. This excessive growth of HABs lead to hypoxic environments, wherein submerged plants and animals cannot survive, creating ‘dead zones’. This causes a chain reaction within an ecosystem, causing ecological damage and jeopardizing ecosystem services. These blooms are the leading cause of water pollution and have emerged as a major regional and global environmental issue. Initiatives to restore Lake Erie have been launched since the 1970s but have been criticized for a lack of enforcement and coordination. This document will outline governance measures that the International Joint Commission can use to control and mitigate Lake Erie's phosphorus eutrophication. The recommendations include implementing Nutrient Management Program and DPSIR model for long-term sustainability. Additionally, it urges for ecological engineering investment.

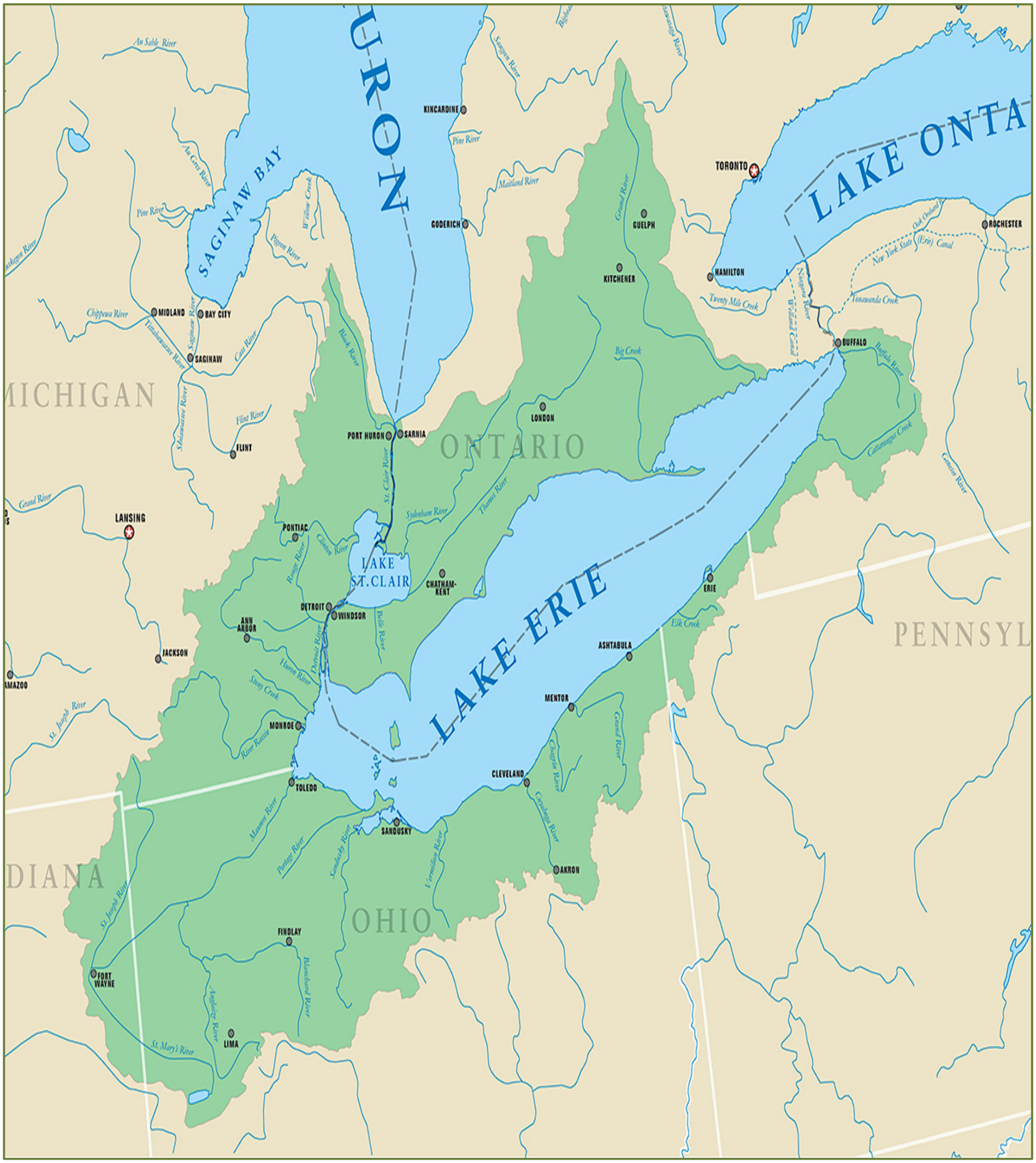

Figure 1: *Map of Lake Erie (Sea Grant Michigan, 2021).*

Lake Erie Conservation:

Tackling Phosphorus Eutrophication

Foundational Science: Discussion & Analysis

Anthropogenic disturbance in biogeochemical flows has created a shift in aquatic ecosystems. Non-point sources of agricultural pollution pose challenges within water bodies, wherein nitrogen and phosphorus flows have led to human induced eutrophication. On both a regional and global scale, there has been a rise in these flows, which has had a direct effect on changes in both aquatic and terrestrial habitats, serving as a catalyst for climate change (Johan et al.,2009).

Lake Erie is North America's fourth-largest lake that borders Canada (Ontario) and the United States (New York, Pennsylvania, Ohio, Michigan) as seen in Figure 1. The lake is home to major commercial fisheries and provides drinking water to over 13 million people (The OEC,2021). In 2018, the lake accumulated more than $357 million in tourism in the United States, creating 13,918 tourism-related jobs. (Johnston, 2019). However, the lake has been subjected to severe eutrophication for many decades, posing a transboundary threat to socioeconomic and environmental systems.

A RUNDOWN OF EUTROPHICATION

The process by which a body of water becomes increasingly enriched with nutrients and minerals, resulting in excessive algal growth, is known as eutrophication (NOS,2021). Since crops require high phosphorus and nitrogen inputs, farmers depend on the use of fertilisers. Due to its ability to accelerate plant growth, phosphorus, among other nutrients, is widely found in fertilizers. As a result of surface water run-off and precipitation, excessive fertilizer nutrients accumulate bodies of water. Phosphorus boosts surface water productivity thereby stimulating the growth of Harmful Algae Blooms- HABs (Sharpley, 2001). When the population of HABs on the flourishes, it blocks out the sunlight, halting photosynthesis. Thus, submerged aquatic plants and algae, perish. Aerobic & Anaerobic bacteria decompose the detritus with the remaining oxygen, which creates a hypoxic environment. [1] This thereby is detrimental to aquatic animals present within the habitat. Figure 2 illustrates the role of phosphorus in intensifying eutrophication, and its destructive effect upon an aquatic ecosystem.

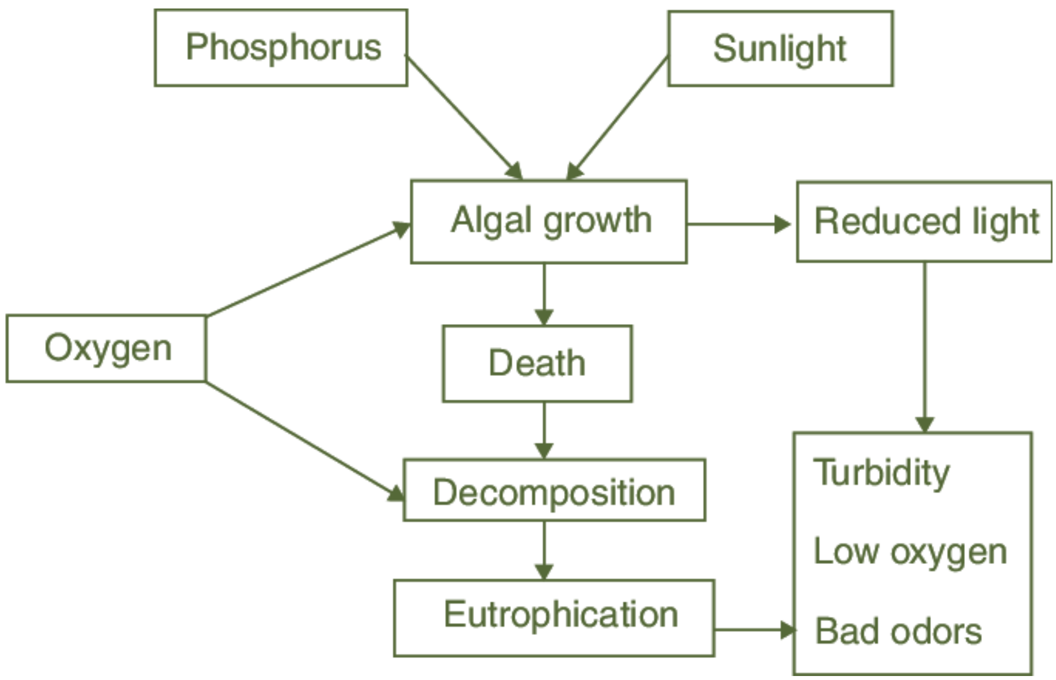

Figure 2: *Diagram illustrating the effects of phosphorus on eutrophication (Elsevier Inc., 2013)*

This over-reliance on fertilizer, which induces phosphorus eutrophication, is economically damaging, biologically ineffective, and endangers aquatic ecosystems. (Guignard et al., 2017). Moreover, rising climates warm water bodies, increasing productivity of surface water, triggering the growth of algae, further contributing to eutrophication (UOM,2019). The presence of eutrophication results in a decrease in revenue generated through recreational (tourism) and ecosystem services (fishing etc.) (Munn et al., 2018). If the blooms at Lake Erie are not

[1] **Hypoxia:** low levels of oxygen present. Hypoxic environments are incapable of supporting life and thus become "dead zones," destroying aquatic ecosystems (National Ocean Service,2021).

addressed, it is estimated that the lake will cost $270 million per year for the next 30 years to maintain (Haggert, 2019). 'Dead zones' are large areas of hypoxic waters and are found 50 feet below Lake Erie (CWD, 2021). These conditions are unsuitable for fish and plants, resulting in the extinction of an ecosystem, creating loss at various levels of the food chain. Zebra Mussels, an invasive indicative species that thrive in high phosphorus levels, have colonized Lake Erie (Vanderploeg et al., 2001). Figure 3 illustrates the progress of HABs in Lake Erie in 2011, as a result of storm runoff.

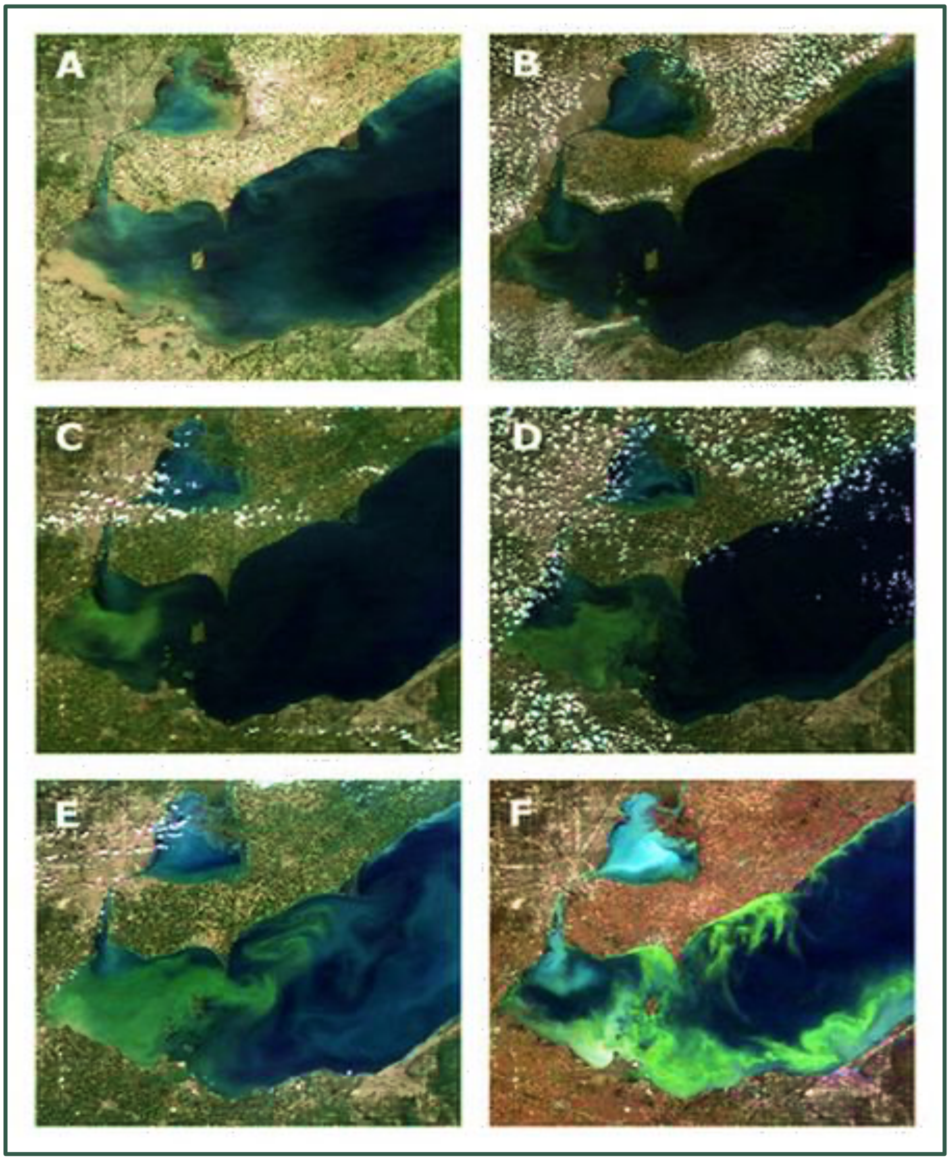

Figure 3: *Satellite imagery of Algal growth in Lake Erie's Western Basins 2011 (Mangels, 2013)*

Assessment of Existing Governance

Formed in 1909, The International Joint Commission (IJC) aims to resolve differences between The US and Canada under the 'Boundary Water Treaty' (IJC,2020). The IJC's "Great Lakes Water Quality Agreement GLWQA," signed in 1972, was the first initiative to protect ecosystems across international borders (Tschorke, 2008). The treaty's primary objective at the time was to reduce human-induced pollution by limiting phosphorus loadings and encouraging wastewater clean - up. IJC received praise from international actors for their transboundary cooperation, and Lake Erie significantly improved (IJC,2021). Figure 4 depicts the moderation in management prospects that the GLWQA have made since 1972. These changes were made as the treaty was criticised for being outdated and unclear in it's intentions (Tschorke, 2008).

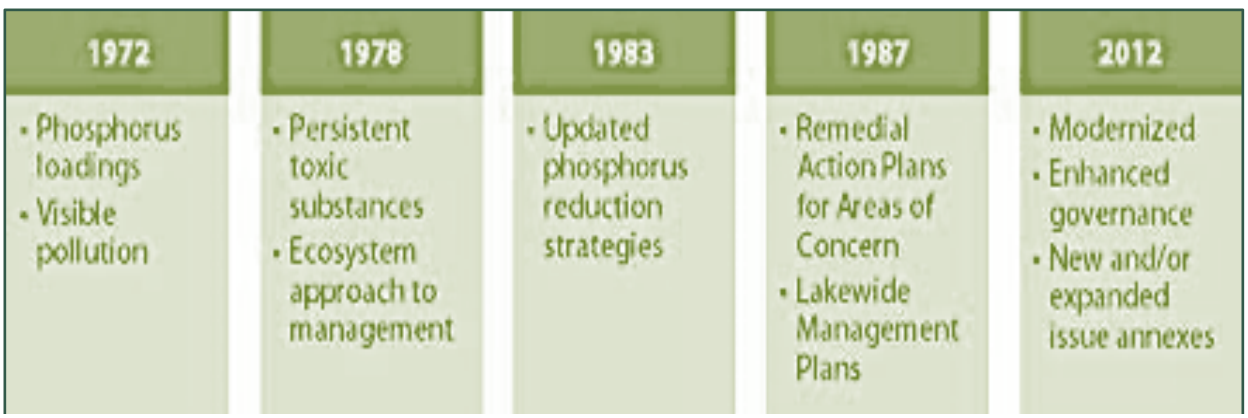

Figure 4: *Updates made to the GLWQA (Binational, n.d.)*

Figure 5 presents the total annual phosphorus loadings following the treaty's implementation. The treaty was effective in setting phosphorus loading targets, and a decrease in its use can be seen until the end of the 1980s; however, despite ongoing efforts to reduce discharges, HABs in Lake Erie have increased since the 1990s (US EPA, 2021). Poor governance is one of the reasons for this. The treaty lacks accountability, wherein citizens and actors are unaware of their roles (Tschorke, 2008). Without a sense of responsibility, critical actors are unable to deliver on commitments, resulting in lower engagement. Furthermore, the treaty was deemed to 'lack enforcement mechanisms,' preventing them from achieving the full extent of their goals (Ibid.)

This is because IJC is not legally binding. Therefore, in order to tackle phosphorus eutrophication in Lake Erie the treaty must be incorporated into transboundary domestic law.

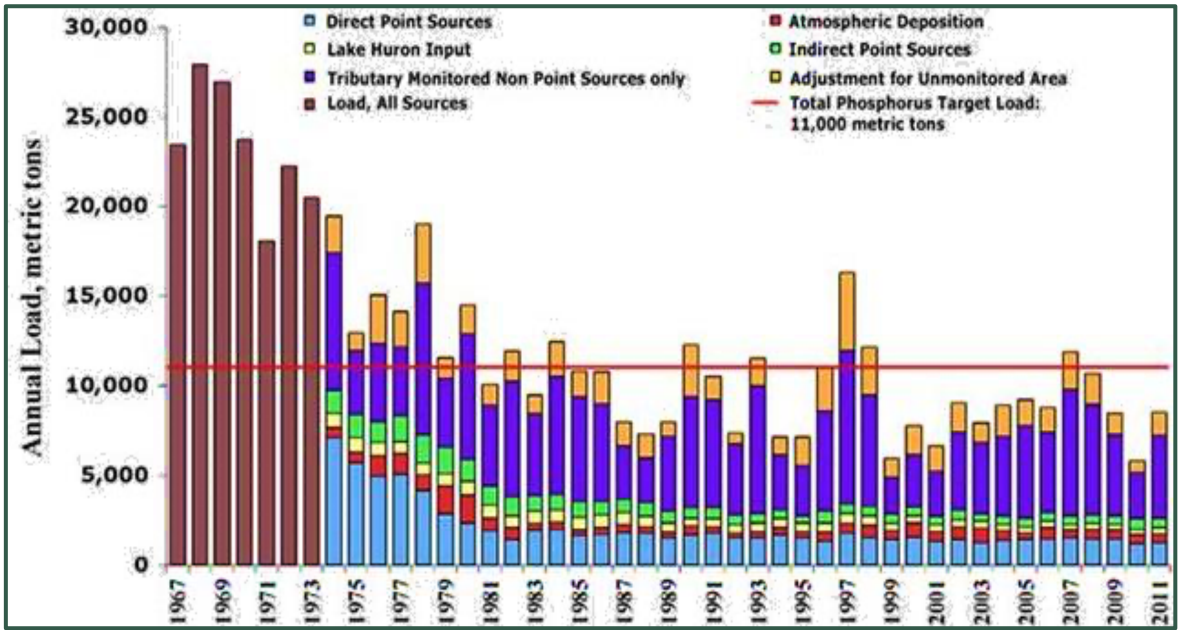

Figure 5*: Phosphorus Loadings overtime in Lake Erie* (Scavia et al., 2014)

In 2010, the US Environmental Protection Agency launched the 'Great Lakes Restoration Initiative' (Fortin, 2020). Figure 6 presents their areas of focus in the past decade.

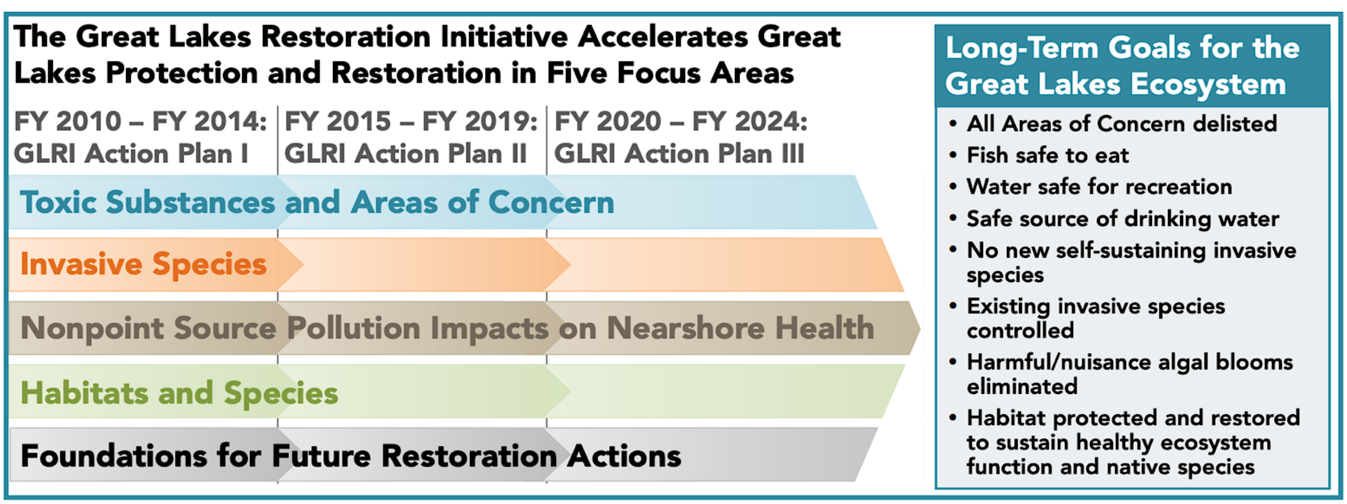

Figure 6: *Long term Goals for the GLRI (GLRI Action Plan, 2019)*

In 2020, the Agency invested approximately $11 million in the development of 20 projects with the goal of reducing phosphorus loading in the Great Lakes (Ibid.). This demonstrates the government's determination to keep operations running in order to carry out plans for lake recovery. However, in 2017, Lake Erie experienced an algal bloom that stretched over 1.5 kilometres in the Western Basin (NOAA, 2020 as cited in DeGood, 2020). This therefore attested to the agency's ineffectiveness. Some of the reasons for this might include poorly coordinated restoration efforts and a lack of a comprehensive plan (CRS report, 2013). Coordination failure frequently results in a gap in data distribution, rendering organizations ineffective.

Environmental collaboration should be prioritized by policymakers when developing recommendations and policies. Transboundary cooperation and novel governance approaches are key to restore Lake Erie.

Governance Recommendations

Mitigating phosphorus eutrophication in Lake Erie will necessitate collaborative efforts from policymakers, researchers and communities. This brief recommends that the International Joint Commission implement the following measures to reduce anthropogenic and ecological stressors:

Reduction of Anthropogenic Stressors

1. *Implement transboundary "Nutrient Management and Monitoring" schemes.*

The reduction of excessive fertiliser has no effect upon crop growth and thus poses minimal risk to farmers (Harrison et al., 2014). Lake Erie's Western Basin must be assessed for phosphorus concentrations, and preliminary research must aid in the development of monitoring schemes. Determining the target nutrients that crops require, through tests conducted by the IJC, is essential, particularly in farms that are in immediate proximity to the lake (Beegle, 2014). According to studies, farmers who adhere to the schemes use lower phosphorus concentrations than farmers who do not. (Shepard, 2005). The Success of the Nutrient Management schemes is seen in the restoration of Tampa Bay in Florida, which suffered from nutrient pollution (Greening et al.,2014).

Policy suggestions include:

- Providing farmers with access to educational materials regarding excessive fertilizer use, with a focus on the ecological threats (Glynn, 2020). Communities must agree on quantifiable restoration goals (Greening et al., 2014).
- Documentation of Nutrient Loadings by farmers to ensure accountability (Precision Agriculture, n.d.) Farmers should provide documentation of nutrient loadings to the IJC when called upon.
- Collaboration between the IJC and the Great Lakes Restoration Initiative, to aid in the management strategies and monitoring for Lake Erie

2. *Application of the 'Drivers Pressures State Impacts Responses (DPSIR) Model to ensure long term sustainability.*

The DPSIR model identifies the interaction between society and the environment and is effective in analysing causes for environmental pressures through human-induced malpractice (Food Safety and Environmental, 2021). Therefore, addressing each anthropogenic stressor of phosphorus eutrophication is vital to establish long term sustainability in Lake Erie. A successful example of the DPSIR Framework is seen in the Maldives, wherein their Government introduced a Community Based Management Scheme to solve human induced waste at an island level and reflected the community's willingness to adopt green programs through the use of the framework (Shadiya and Shareef, 2020).

Figure 7 displays a sample DSPIR framework curated for marine eutrophication that the IJC could potentially model as a part of their frameworks. To personalize a framework, the IJC's Great Lakes team must conduct a series of tests and cross-sectional research approaches in cities bordering Lake Erie. Data collection is vital in the development of the lake.

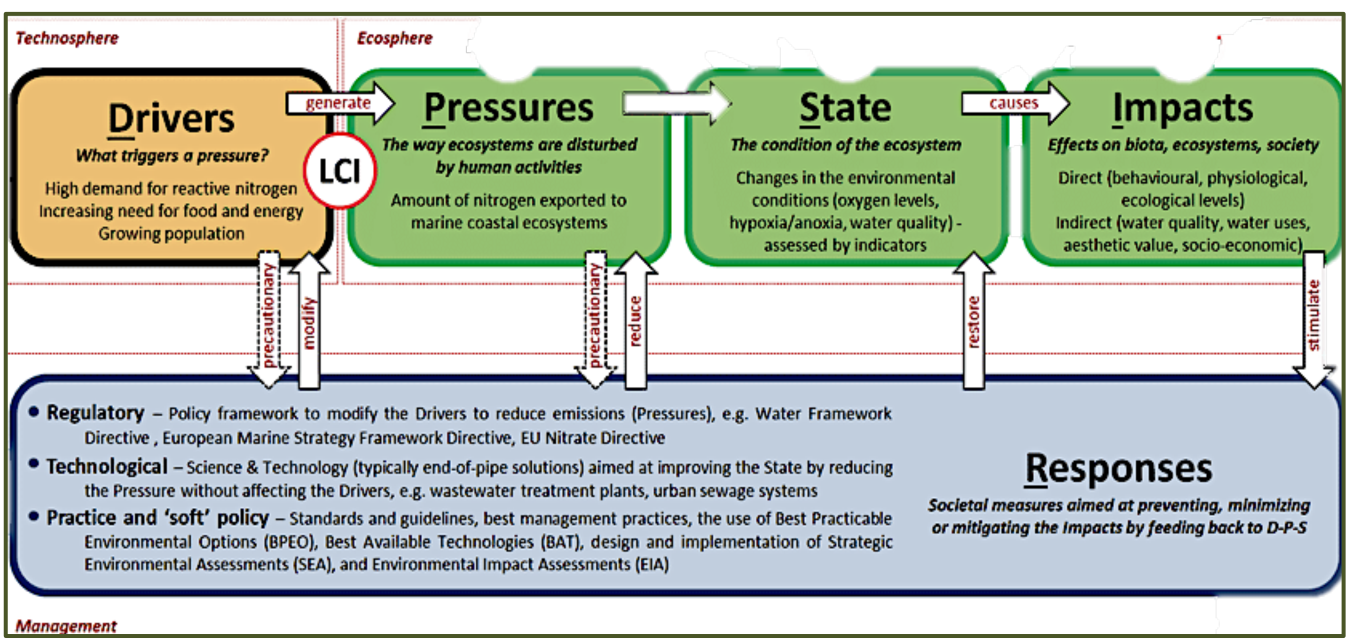

Figure 7: *The DPSIR Framework applicable to Eutrophication (Cosme and Niero, 2017)*

Reduction of Environment Stressors

3. *Invest in ecological engineering to restore Lake Erie*

The IJC must aim to obtain funding from governmental bodies to introduce biotechnological interventions within Lake Erie as a method of tackling nutrient surface run-off in Lake Erie:

Buffer Zones are barriers of plants bordering lakes to absorb excessive nutrient run-off (George et al., 2021). Since Lake Erie is subjected to storm run-off, these should be effective around the Western Basins. They offer biodiversity and introduce employment opportunities for farmers (Naiman et al., 1993). A Study in Canada observed the effectiveness of buffer zones to achieve reductions in nutrient loads over a 10-year period (Dunn et al., 2011).

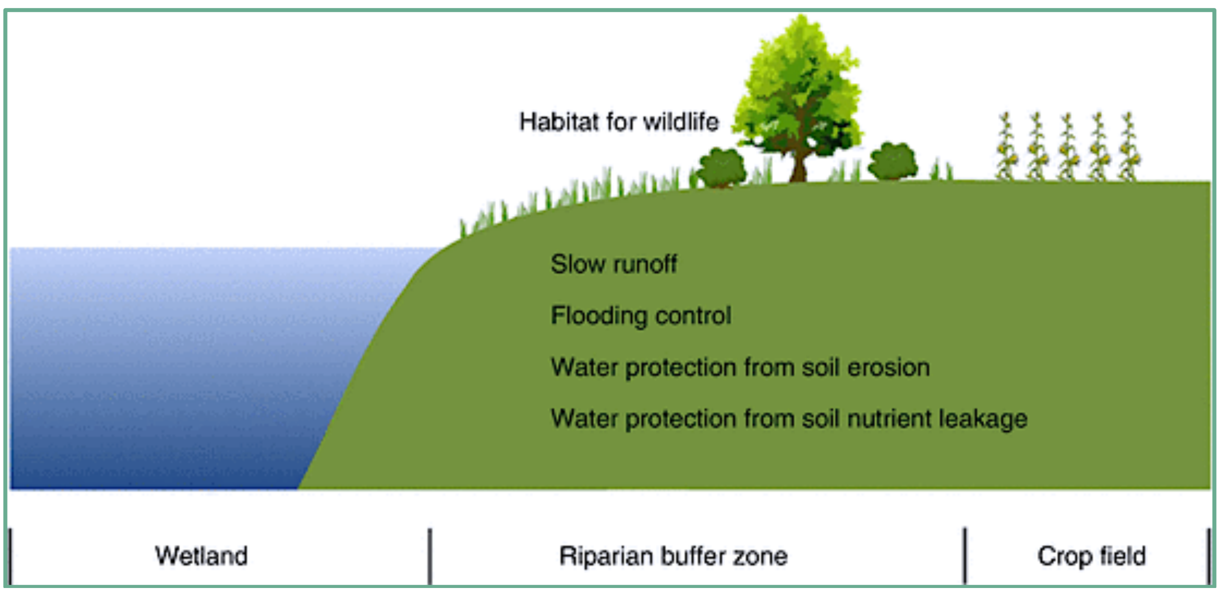

Figure 8: *Buffer Zone for wetlands (Ma, 2016)*

Policy Suggestions:

- Create economic incentives and subsidies to encourage investment from organisations or individuals
- Conduct extensive preliminary research on the best suited crops for absorbing nutrients (Oregon NRCS, 2018)

List of References

Beegle, D., 2014. *Nutrient Management Planning: An Overview*. [online] Penn State Extension. Available at: <https://extension.psu.edu/nutrient-management-planning-an-overview> [Accessed 14 April 2021].

Cosme, N. and Niero, M., 2017. Modelling the influence of changing climate in present and future marine eutrophication impacts from spring barley production. *Journal of Cleaner Production*, 140, pp.537-546.

CRS Report, 2013. The Great Lakes Restoration Initiative: Background and Issues. [online] (Specialist in Natural Resources Policy). Available at: <https://www.everycrsreport.com/files/20130930_R43249_13c15546885449a4783842410bb82d7b0c46e73b.pdf> [Accessed 21 March 2021].

CWD (Cleveland Water Dep.) 2021. *Lake Erie*. [online] Available at: <http://www.clevelandwater.com/your-water/lake-erie> [Accessed 14 April 2021].

DeGood, K., 2020. *A Call to Action on Combating Nonpoint Source and Stormwater Pollution - Center for American Progress*. [online] Center for American Progress. Available at: <https://www.americanprogress.org/issues/economy/reports/2020/10/27/492149/call-action-combating-nonpoint-source-stormwater-pollution/> [Accessed 13 April 2021].

Dunn, A., Julien, G., Ernst, W., Cook, A., Doe, K. and Jackman, P., 2011. Evaluation of buffer zone effectiveness in mitigating the risks associated with agricultural runoff in Prince Edward Island. *Science of The Total Environment*, 409(5), pp.868-882.

Elsevier Inc., 2013. *Effects of Phosphorus eutrophication*. [image] Available at: <https://www.researchgate.net/profile/Amir-Mohaghegh-Motlagh/publication/273497351/figure/fig2/AS:667785579491332@1536223897184/The-effect-of-phosphorus-on-eutrophication.png> [Accessed 12 April 2021].

Food Safety and Environmental, 2021. *1.3.3 DPSIR*. [video] Available at: <https://www.youtube.com/watch?v=ZZi5Y6iBm1Y> [Accessed 14 April 2021].

Fortin, D., 2020. *EPA, Members of Congress, Partners and Stakeholders celebrate a decade of GLRI success | US EPA*. [online] US EPA. Available at: <https://www.epa.gov/newsreleases/epa-members-congress-partners-and-stakeholders-celebrate-decade-glri-success#:~:text=GLRI%20was%20launched%20in%202010,of%20the%20Great%20Lakes%20basin.> [Accessed 30 April 2021].

George, M., Jackson, R. and Boyd, C., 2021. *A Scientific Assessment of the Effectiveness of Riparian Management Practices*. 5th ed. [ebook] University of California. Available at: <https://www.researchgate.net/profile/Kenneth-Tate/publication/240613728_A_Scientific_Assessment_of_the_Effectiveness_of_Riparian_Management_Practices/links/02e7e51c62258f1915000000/A-Scientific-Assessment-of-the-Effectiveness-of-Riparian-Management-Practices.pdf> [Accessed 30 March 2021].

GLRI Action Plan, 2019. *GREAT LAKES RESTORATION INITIATIVE ACTION PLAN*. 3rd ed. [ebook] p.2. Available at: <https://www.epa.gov/sites/production/files/2019-10/documents/glri-action-plan-3-201910-30pp.pdf> [Accessed 13 April 2021].

Glynn, D., 2020. *Environment - Why Nutrient Management Planning Is So Important For Farmers - Teagasc | Agriculture and Food Development Authority*. [online] Teagasc.ie. Available at: <https://www.teagasc.ie/news--

events/daily/environment/why-nutrient-management-planning-is-so-important-for-farmers.php#:~:text=Implementing%20a%20Nutrient%20Management%20Plan,-This%20can%20optimise&text=On%20most%20farms%20nutrients%20are,the%20soil%20as%20organic%20manure.&text=Planning%20helps%20to%20optimise%20the,up%20and%20lessen%20environmental%20risks.> [Accessed 14 April 2021].

Greening, H., Janicki, A., Sherwood, E., Pribble, R. and Johansson, J., 2014. Ecosystem responses to long-term nutrient management in an urban estuary: Tampa Bay, Florida, USA. *Estuarine, Coastal and Shelf Science*, 151, pp.A1-A16.

Guignard, M., Leitch, A., Acquisti, C., Eizaguirre, C., Elser, J., Hessen, D., Jeyasingh, P., Neiman, M., Richardson, A., Soltis, P., Soltis, D., Stevens, C., Trimmer, M., Weider, L., Woodward, G. and Leitch, I., 2017. Impacts of Nitrogen and Phosphorus: From Genomes to Natural Ecosystems and Agriculture. *Frontiers in Ecology and Evolution*, 5. Available at: < DOI: 10.3389/fevo.2017.00070 >

Haggert, A., 2019. *Algal blooms to cost Lake Erie tourism economy $110M: study | CBC News*. [online] CBC. Available at: <http://cbc.ca/news/canada/windsor/algal-bloom-economic-cost-lake-erie-1.5221597#:~:text=Results%20of%20an%20economic%20costs,%24110%20million%20equivalent%20annual%20cost.&text=%22We%20knew%20this%20problem%20was,said%20report%20contributor%20Brad%20Bass.> [Accessed 13 April 2021].

Harrison, P., Berry, P., Simpson, G., Haslett, J., Blicharska, M., Bucur, M., Dunford, R., Egoh, B., Garcia-Llorente, M., Geamănă, N., Geertsema, W., Lommelen, E., Meiresonne, L. and Turkelboom, F., 2014. Linkages between biodiversity attributes and ecosystem services: A systematic review. *Ecosystem Services*, 9, pp.191-203.

IJC International Joint Commission. 2020. *Mission and Mandates | International Joint Commission*. [online] Available at: <https://ijc.org/en/who/mission> [Accessed 13 April 2021].

IJC International Joint Commission. 2021. *History of the Great Lakes Water Quality Agreement*. [online] Available at: <https://www.ijc.org/en/what/glwqa-history> [Accessed 13 April 2021].

Johan, R. and Will, S., 2009. *Planetary Boundaries: Exploring the Safe Operating Space for Humanity., Ecology and Society: A Journal of Integrative Science for Resilience and Sustainability*, [online] Ecology and Society 14(2): 32.

Johnston, L., 2019. *11 million tourists visited Lake Erie Shores and Islands in 2018 - Rock The Lake*. [online] Rock The Lake. Available at: <http://www.rockthelake.com/buzz/2019/04/tourism-generated-1-4-billion-in-lake-erie-shores-and-islands-in-2014/#:~:text=11%20million%20tourists%20visited%20Lake%20Erie%20Shores%20and%20Islands%20in%202018,-By%20Laura%20Johnston&text=Lake%20Erie%20Shores%20and%20Islands%20welcomed%20more%20than%2011%20million,according%20to%20visitors%20bureau%20statistics.&text=All%20that%20spending%20generated%2013%2C918,million%20in%20tourism%2Dsupported%20wages.> [Accessed 13 April 2021].

Kottke, C., 2021. *High fertilizer prices could last through spring*. [online] Wisfarmer.com. Available at: <https://www.wisfarmer.com/story/news/2021/03/09/high-fertilizer-prices-could-last-through-spring-planting-season/6880888002/> [Accessed 13 April 2021].

Ma, M., 2016. Riparian Buffer Zone for Wetlands. *The Wetland Book*, pp.1-9.

Mangels, J., 2013. *Satellite imagery of Algal growth in Lake Erie’s Western Basin*. [image] Available at: <https://www.cleveland.com/science/2013/04/record-sized_lake_erie_algae_b.html> [Accessed 13 April 2021].

Munn, M., Frey, J., Tesoriero, A., Black, R., Duff, J., Lee, K., Maret, T., Mebane, C., Waite, I. and Zelt, R., 2018. Understanding the influence of nutrients on stream ecosystems in agricultural landscapes. *Circular*, pp.1-80.
n.d. *About the Great Lakes Water Quality Agreement*. [online] Available at: <https://binational.net/glwqa-aqegl/> [Accessed 13 April 2021].

Naiman, R., Decamps, H. and Pollock, M., 1993. The Role of Riparian Corridors in Maintaining Regional Biodiversity. *Ecological Applications*, 3(2), pp.209-212.

National Ocean Service., 2021.Oceanservice.noaa.gov. *Low or depleted oxygen in a water body often leads to 'dead zones '— regions where life cannot be sustained.*. [online] Available at: <https://oceanservice.noaa.gov/hazards/hypoxia/> [Accessed 13 April 2021].

NOAA, 2021. Great Lakes. [online] Coast.noaa.gov. Available at: <https://coast.noaa.gov/states/fast-facts/great-lakes.html#:~:text=More%20than%2030%20million%20people,percent%20of%20the%20Canadian%20population.&text=The%20U.S.%20Great%20Lakes%20maritime,and%20recreation%20to%20marine%20transportation.> [Accessed 14 April 2021].

NOAA, 2021. *Lake Erie HAB*. [online] Tidesandcurrents.noaa.gov. Available at: <https://tidesandcurrents.noaa.gov/hab/lakeerie.html> [Accessed 13 April 2021].

NOS Oceanservice.noaa.gov. 2021. *What is eutrophication?*. [online] Available at: <https://oceanservice.noaa.gov/facts/eutrophication.html> [Accessed 12 April 2021].

Oregon NRCS, 2018. *Contour Stripcropping*. [online] Web.archive.org. Available at: <https://web.archive.org/web/20120220121959/http://www.or.nrcs.usda.gov/technical/conservation-planning-and-conservation-records/contourstripcropping.html> [Accessed 14 April 2021].

Precision Agriculture, n.d. *Benefits of Documenting Data In Farm Management*. [online] Precisionagricultu.re. Available at: <https://precisionagricultu.re/benefits-of-documenting-data-in-farm-management/> [Accessed 14 April 2021].

Scavia, D., David Allan, J., Arend, K., Bartell, S., Beletsky, D., Bosch, N., Brandt, S., Briland, R., Daloğlu, I., DePinto, J., Dolan, D., Evans, M., Farmer, T., Goto, D., Han, H., Höök, T., Knight, R., Ludsin, S., Mason, D., Michalak, A., Peter Richards, R., Roberts, J., Rucinski, D., Rutherford, E., Schwab, D., Sesterhenn, T., Zhang, H. and Zhou, Y., 2014. Assessing and addressing the re-eutrophication of Lake Erie: Central basin hypoxia. *Journal of Great Lakes Research*, 40(2), pp.226-246.

Sea Grant Michigan, 2021. *LAKE ERIE*. [image] Available at: <https://www.michiganseagrant.org/wp-content/uploads/2018/10/Erie-Basin-Map-1200px.jpg> [Accessed 13 April 2021].

Shadiya, F. and Shareef, A., 2020. *Application of DPSIR Framework to Explore Effectiveness of Solid Waste Management in the Maldives.*.
Sharpley, A., 2001. *Managing Phosphorus for Agriculture and the Environment*. [online] Pennsylvania Nutrient Management Program. Available at: <https://extension.psu.edu/programs/nutrient-management/educational/soil-fertility/managing-phosphorus-for-agriculture-and-the-environment> [Accessed 3 April 2021].

Shepard, R., 2005. Nutrient management planning: Is it the answer to better management?. *Journal of Soil and Water Conservation*, [online] Vol. 60, Issue 4.

THE OEC. 2021. *Lake Erie | Ohio Environmental Council*. [online] Available at: <https://theoec.org/clean-water/lake-erie/#:~:text=Lake%20Erie%20is%20the%20shallowest,ot

her%20four%20Great%20Lakes%20combined.>
[Accessed 25 April 2021].

Tschorke, A., 2008. *Great Lakes Water Quality Agreement: Is Honesty Without Accountability or Enforcement Still Enough?*. [online] Scholarship.law.missouri.edu. Available at: <https://scholarship.law.missouri.edu/cgi/viewcontent.cgi?article=1314&context=jesl> [Accessed 13 April 2021].

UOM (University of Minnesota)., 2019. *Eutrophication of lakes will significantly increase greenhouse gas emissions*. [online] Available at: <https://www.sciencedaily.com/releases/2019/03/190326081426.htm> [Accessed 13 April 2021].

US EPA, 2021. *Recommended Binational Phosphorus Targets*. [online] Available at: <https://www.epa.gov/glwqa/recommended-binational-phosphorus-targets> [Accessed 13 April 2021].

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