Draft

Saginaw Bay Watershed Research Bibliography

Developed by student interns Saginaw Bay Environmental Science Institute at SVSU.

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This document will be edited and updated as needed. Please submit literature citations to sbesi@svsu.edu with "Saginaw Bay Literature" in the subject line. Your submission will be reviewed and included if appropriate to the context of this bibliography.

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Biological

I. Plants

a. Total Phytoplankton

Auer, M. T., Kieser, M. S., & Canale, R. P. (1986). Identification of critical nutrient levels through field verification of models for phosphorus and phytoplankton growth. *Canadian Journal of Fisheries and Aquatic Sciences*, *43*(2), 379-388.

- Growth rates based on different types of phosphorus (dissolved and stored) were found using Monod and Droop Models for the Great Lakes and Saginaw Bay.

Bierman, V. J., & Dolan, D. M. (1981). Modeling of phytoplankton-nutrient dynamics in Saginaw Bay, Lake Huron. *Journal of Great Lakes Research*, *7*(4), 409-439.

- A simulation model was developed for five groups of phytoplankton, included nutrients, and was designed specifically for the Saginaw Bay.

Bierman Jr, V. J., & Dolan, D. M. (1986). Modeling of phytoplankton in Saginaw Bay: I. Calibration phase. *Journal of Environmental Engineering*, *112*(2), 400-414.

- Phytoplankton simulation model for the Saginaw Bay.

Bierman Jr, V. J., & Dolan, D. M. (1986). Modeling of phytoplankton in Saginaw Bay: II. Post-audit phase. *Journal of Environmental Engineering*, *112*(2), 415-429.

- Phytoplankton simulation model for the Saginaw Bay.

Di Toro, D. M., & Matystik Jr, W. F. (1980). Mathematical Models Of Water Quality In Large Lakes Part 1: Lake Huron And Saginaw Bay. *U.S. Environmental Protection Agency.*

- A model was developed to include nutrients as well as plankton biomass and was calibrated with water quality data after statistical analysis.

Dolan, D. M., Bierman, V. J., Dipert, M. H., & Geist, R. D. (1978). Statistical analysis of the spatial and temporal variability of the ratio chlorophyll a to phytoplankton cell volume in Saginaw Bay, Lake Huron. *Journal of Great Lakes Research*, *4*(1), 75-83.

- The measurement of chlorophyll a has been used to determine the biomass of phytoplankton. Statistical analysis was necessary, which showed the variability in the assumption.

Moll, R. A., Davis, C. O., & Schelske, C. L. (1980). Phytoplankton productivity and standing crop in the vicinity of the Lake Huron-Saginaw Bay front. *Journal of Great Lakes Research*, *6*(3), 232-246.

- High bacterial activity and chlorophyll biomass were found along with low carbon uptake. These results indicated that the phytoplankton community is old and/or aging. Most phytoplankton undergoing decomposition would settle before being mixed into the outer bay.

Munawar, M., & Munawar, I. F. (2001). An overview of the changing flora and fauna of the North American Great Lakes. Part I: Phytoplankton and microbial food web. *The Great Lakes of the World (GLOW): Foodweb, Health and Integrity*, 219-275.

- The invasion of zebra mussels has drastically changed the community of phytoplankton by altering the diversity, reducing biomass, and changing average size. The filtering activity of the invasive zebra mussels has changed the phytoplankton community, thus changing the dynamics of the food web.

b. Algae

Armenio, P. M., Mayer, C. M., Heckathorn, S. A., Bridgeman, T. B., & Panek, S. E. Resource contributions from dreissenid mussels to the benthic algae *Lyngbya wollei* (Cyanobacteria) and *Cladophora glomerata* (Chlorophyta). *Hydrobiologia*, 1-17.

- In this study, the algae *Cladophora* showed an increase in biomass and *L. wollei* showed an increase in nutrients due to coexistence with *Dreissena*.

Bierman, V. J., Dolan, D. M., Kasprzyk, R., & Clark, J. L. (1984). Retrospective analysis of the response of Saginaw Bay, Lake Huron, to reductions in phosphorus loadings. *Environmental Science & Technology*, *18*(1), 23-31.

- Chlorophyll a was shown to decrease at a larger percentage than the percentage of the phosphorus decrease. When including Secchi depth, it was suggested that the re-suspension of sediment was due to waves which accounted for the unexpected results seen between phosphorus, chlorophyll a, and inverse Secchi depth percentages.

Carr, G. M., Duthie, H. C., & Taylor, W. D. (1997). Models of aquatic plant productivity: A review of the factors that influence growth. *Aquatic Botany*, *59*(3), 195-215.

- This study confronts the aspects of plant and algae modeling that are lacking, need verification, or further research.

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

- It was found that green algae and filamentous algae were in greater abundance than macroscopic primary producers. Red algae was the dominant taxa found of the filamentous algae.

Michalak, A. M., Anderson, E. J., Beletsky, D., Boland, S., Bosch, N. S., Bridgeman, T. B., ... & Zagorski, M. A. (2013). Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions. *Proceedings of the National Academy of Sciences*, 110(16), 6448-6452.

- Extensive algal blooms were exacerbated due to excess nutrient loading, climate, and lack of flow in Lake Erie. Predictions of harmful algal blooms are expecting an increase in instances like these.

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

- *Microcystis* was found to be most concentrated at the mouth of the Saginaw River. The community of phytoplankton was comprised primarily of diatoms and cyanobacteria. Trends were not easily defined as there was a great deal of variability given by numerous environmental factors.

Rinta-Kanto, J. M., Ouellette, A. J. A., Boyer, G. L., Twiss, M. R., Bridgeman, T. B., & Wilhelm, S. W. (2005). Quantification of toxic *Microcystis* spp. during the 2003 and 2004 blooms in western Lake Erie using quantitative real-time PCR. *Environmental Science & Technology*, *39*(11), 4198-4205.

- In 2003 and 2004, levels of the microcystin toxin were found in Lake Erie at greater concentrations than the WHO water quality standard allows. Fragments of 16S rDNA were used for the quantification of *Microcystis* using PCR to elucidate abundance and distribution.

Smith, V. H. (1985). Predictive models for the biomass of blue-green algae in lakes1. *JAWRA Journal of the American Water Resources Association*, *21*(3), 433-439.

- Models used for prediction of blue-green algae in the most problematic season using a model that includes total phosphorus, algae biomass, and depth.

Smith, V. H. (1986). Light and nutrient effects on the relative biomass of blue-green algae in lake phytoplankton. *Canadian Journal of Fisheries and Aquatic Sciences*, *43*(1), 148-153.

- The biomass of phytoplankton is dependent upon light, nitrogen, and phosphorus. It was proven that when nitrogen and phosphorus are at a fixed ratio the biomass

is dependent upon light (when it decreases biomass increases) and the light, if fixed, will have a nitrogen to phosphorus ratio that will decrease as biomass increases.

Vanderploeg, H. A., Liebig, J. R., Carmichael, W. W., Agy, M. A., Johengen, T. H., Fahnenstiel, G. L., & Nalepa, T. F. (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), 1208-1221.

- *Microcystis aeruginosa* was proven to be rejected by zebra mussels, which contributes to the overfeeding of other algae while allowing harmful blooms.

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

- This article points out the apparent issues in dealing with toxicity from cyanobacteria. It mentions gaps in knowledge that should be filled to benefit ecological and socioeconomic issues that can be related with water fouling.

i. <u>Cladophora</u>

Auer, M. T., Canale, R. P., Grundler, H. C., & Matsuoka, Y. (1982). Ecological studies and mathematical modeling of *Cladophora* in Lake Huron: 1. Program description and field monitoring of growth dynamics. *Journal of Great Lakes Research, 8*(1), 73-83.

Auer, M. T., & Canale, R. P. (1982). Ecological studies and mathematical modeling of *Cladophora* in Lake Huron: 2. Phosphorus uptake kinetics. *Journal of Great Lakes Research, 8*(1), 84-92.

- This study focused on the factors that affect the rate of phosphorus uptake, the internal phosphorus pool size and the dissolved phosphorus. Simulation of *Cladophora* growth can be found using the mathematical models.

Auer, M. T., & Canale, R. P. (1982). Ecological studies and mathematical modeling of *Cladophora* in Lake Huron: 3. The dependence of growth rates on internal phosphorus pool size. *Journal of Great Lakes Research, 8*(1), 93-99.

- Photosynthesis, respiration, and carbon content were measured to determine growth rate of cladophora based on the size of the internal phosphorus pool. Looking at this relationship for use in phosphorus management was suggested.

Auer, M. T., Graham, J. M., Canale, R. P., & Hoffmann, J. P. (1982). Ecological studies and mathematical modeling of *Cladophora* in Lake Huron: 4. Photosynthesis and respiration as functions of light and temperature. *Journal of Great Lakes Research*, *8*(1), 100-111.

- The effects of amount of light, different temperatures, variation in respiration and growth were explored.

Auer, M. T., & Canale, R. P. (1982). Ecological studies and mathematical modeling of *Cladophora* in Lake Huron: 5. Model development and calibration. *Journal of Great Lakes Research*, *8*(1), 112-125.

- *Cladophora* biomass model developed for spatial and temporal variations seen with variable amounts of phosphorus and trends in spatial variation were observed. Results were collected to aid in phosphorus management.

Auer, M. T., Canale, R. P., & Graham, J. M. (1982). Ecological studies and mathematical modeling of *Cladophora* in Lake Huron: 6. Seasonal and spatial variation in growth kinetics. *Journal of Great Lakes Research*, *8*(1), 126-133.

- Growth rate in relation to variables such as light, temperature, seasonality, depth and distance from eutrophication sources were used in the model.

Auer, M. T., & Canale, R. P. (1982). Ecological studies and mathematical modeling of *Cladophora* in Lake Huron: 7. Model verification and system response. *Journal of Great Lakes Research*, *8*(1), 134-143.

- It was verified that the model developed worked well in determining *Cladophora* response to changes in phosphorus based on the study using phosphorus removal as a check.

Auer, M. T., & Canale, R. P. (1980). Phosphorus uptake dynamics as related to mathematical modeling of *Cladophora* at a site on Lake Huron. *Journal of Great Lakes Research*, *6*(1), 1-7.

- Kinetic data on phosphorus uptake rates and the variability of phosphorus in the water was used as information in modeling the biomass of *Cladophora*.

Brooks, C., Grimm, A., Shuchman, R., Sayers, M., & Jessee, N. (2015). A satellite-based multi-temporal assessment of the extent of nuisance *Cladophora* and related submerged aquatic vegetation for the Laurentian Great Lakes. *Remote Sensing of Environment*, *157*, 58-71.

- Landsat technology was used to map benthic algae distribution along the near shore areas of the Great Lakes. Percent coverage data was collected.

Depew, D. C., Stevens, A. W., Smith, R. E., & Hecky, R. E. (2009). Detection and characterization of benthic filamentous algal stands (*Cladophora* sp.) on rocky substrata using a high-frequency echosounder. *Limnology and Oceanography: Methods*, *7*(10), 693-705.

- Echo sound technology was used for the determination of percent coverage and height of *Cladophora*.

Higgins, S. N. (2005). Modeling the growth dynamics of *Cladophora* in eastern Lake Erie (Doctoral dissertation, University of Waterloo).

- Different variables in the environment were investigated using a revised version of the *Cladophora* Growth Model to determine the temporal and spatial patterns of *Cladophora*.

Higgins, S. N., Hecky, R. E., & Guildford, S. J. (2008). The collapse of benthic macroalgal blooms in response to self-shading. *Freshwater Biology*, *53*(12), 2557-2572.

- The collapse of algal blooms was attributed to the algae exceeding the critical threshold, resulting in self-shading. Self-shading killed algae cells, thus causing their removal from the algal bloom.

Higgins, S. N., Malkin, S. Y., Todd Howell, E., Guildford, S. J., Campbell, L., Hiriart-Baer, V., & Hecky, R. E. (2008). An ecological review of *Cladophora glomerata* (Chlorophyta) in the Laurentian Great Lakes1. *Journal of Phycology*, *44*(4), 839-854.

- This review points out the historical occurrences of *Cladophora* pre- and post-phosphorus management. It also explores *Cladophora* occurrences pre- and post-mussel invasion, with focus on the dreissenid facilitated changes to the ecosystem.

Houben, A. J. (2008). Organic tissue stoichiometry of *Cladophora glomerata* and its relation to coastal land use in the Laurentian Great Lakes.

- Carbon, nitrogen, and phosphorus ratios were examined using *Cladophora* tissue samples to relate these to land uses in urban and non-urban areas along the Great Lakes.

Lorenz, R. C., Monaco, M. E., & Herdendorf, C. E. (1991). Minimum light requirements for substrate colonization by *Cladophora glomerata*. *Journal of Great Lakes Research*, *17*(4), 536-542.

- It was found that light intensities over 28 $\mu Em^{-2}s^{-1}$ led to better growth of *Cladophora*. Additionally, a model was developed to predict the depth of *Cladophora* colonization based on water quality parameters and light intensity.

Painter, D. S., & Jackson, M. B. (1989). *Cladophora* internal phosphorus modeling: Verification. *Journal of Great Lakes Research*, *15*(4), 700-708.

- This *Cladophora* growth model was verified for the use in determining internal phosphorus for different areas of the Great Lakes.

Stevenson, R. J., & Stoermer, E. F. (1982). Abundance patterns of diatoms on *Cladophora* in Lake Huron with respect to a point source of wastewater treatment plant effluent. *Journal of Great Lakes Research*, *8*(1), 184-195.

- There was a difference seen between the distances from the wastewater discharge (when considering diatoms). A positive relation to the distance and the low occurrence of epiphytic congregations was found and the cause for the low abundance was unknown.

Stevenson, R. J., & Stoermer, E. F. (1982). Seasonal abundance patterns of diatoms on *Cladophora* in Lake Huron. *Journal of Great Lakes Research*, *8*(1), 169-183.

- The temporal and epiphytic relationship between diatoms and *Cladophora* was observed. *Cladophora* had the greatest growth in June and July; for diatoms it was September.

Tomlinson, L. M., Auer, M. T., Bootsma, H. A., & Owens, E. M. (2010). The Great Lakes *Cladophora* model: Development, testing, and application to Lake Michigan. *Journal of Great Lakes Research*, *36*(2), 287-297.

- Development of the Great Lakes Cladophora Model (GLCM) to assess *Cladophora* growth, which has been having negative impacts on near shore sites due to the greater amount of phosphorus, may aid in management decisions.

Wells, J., Kaufman, P., Jones, J., Estabrook, G., & Ghosheh, N. (1982). Contents of some heavy metals in plants from Saginaw Bay (Lake Huron) and some small lakes in wilderness areas of Michigan's Upper Peninsula as analyzed by neutron activation analysis. *Journal of Radioanalytical and Nuclear Chemistry*, *71*(1-2), 97-113.

- The plants close to the mouth of the Saginaw River had very high concentrations of heavy metals. *Cladophora* and *Typha* had the highest concentrations although different parts of each plant had different concentrations of the metals.

Wijesinghe, R. U., Oster, R. J., Haack, S. K., Fogarty, L. R., Tucker, T. R., & Riley, S. C. (2015). Spatial, temporal and matrix variability of *Clostridium botulinum* Type E Toxin Gene (bontE) distribution at beaches in the Great Lakes. *Applied and Environmental Microbiology*.

- Algae, *Cladophora*, was collected to determine the *Clostridium botulinum* type E toxin gene, which was found to be present most in areas of the Great Lakes. Saginaw Bay and Bay City had the highest concentration. This could be due to variable factors that affect water quality.

Wolfe, T. L., & Sweeney, R. A. (1982). Laurentian Great Lakes *Cladophora* annotated bibliography. *Journal of Great Lakes Research*, *8*(1), 201-237.

- 181 references regarding Laurentian Great Lakes *Cladophora*.

c. Macrophytes

Becker, B., & Torbick, N.(2009). Remote Sensing Mapping invasive plants in wetlands. Applied Geosolutions and Central Michigan University.

- This tool gives the ability to track invasive plant species using hyperspectral imagery.

Bourgeau-Chavez, L. L., Laubach, Z. M., Landon, A. J., Banda, E. C., Battaglia, M. J., Endres, S. L., ... & Brooks, C. N. (2015). 15 Great Lakes coastal wetland mapping. *Remote Sensing of Wetlands: Applications and Advances*, 315.

- Multiple sensors have been employed to enhance mapping that is difficult for wetland areas.

Cardinale, B. J., Brady, V. J., & Burton, T. M. (1998). Changes in the abundance and diversity of coastal wetland fauna from the open water/macrophyte edge towards shore. *Wetlands Ecology and Management*, *6*(1), 59-68.

- It was found that spatial distance from the water's edge influenced the diversity and abundance of plankton, fish, and macroinvertebrates. Half of the species examined in the Saginaw Bay had horizontal spatial trends of abundance.

Chambers, P. A., & Kaiff, J. (1985). Depth distribution and biomass of submersed aquatic macrophyte communities in relation to Secchi depth. *Canadian Journal of Fisheries and Aquatic Sciences*, *42*(4), 701-709.

- To determine the depth at which different macrophyte colonization would take place, linear regression models were developed in relation to Secchi depth. Other water quality parameters could be incorporated to improve predictions.

Estabrook, G. F., Burk, D. W., Inman, D. R., Kaufman, P. B., Wells, J. R., Jones, J. D., & Ghosheh, N. (1985). Comparison of heavy metals in aquatic plants on Charity Island, Saginaw Bay, Lake Huron, USA, with plants along the shoreline of Saginaw Bay. *American Journal of Botany*, 209-216.

- A comparison study on heavy metals in macrophytes showed that Charity Island had high concentrations of nine of the metals tested. It was suggested that the mechanism of heavy metal movement is dependent on the metal itself.

Herrick, B. M., & Wolf, A. T. (2005). Invasive plant species in diked vs. undiked Great Lakes wetlands. *Journal of Great Lakes Research*, *31*(3), 277-287.

- Invasive plants were found in both the diked and the undiked wetlands. However, the diked wetlands had more invasive species, increased nutrients, and other factors that could contribute to more water quality issues.

Higman, P. J., Slaughter, B., Campbell, S., & Schools, E. (2010). Early detection of emerging aquatic and wetland invasive plants in Michigan. *Department of Natural Resources and Environment Water Bureau.*

- In order to determine the abundance and distribution of invasive and potentially invasive, non-native plants, several species and study areas were mapped. Management guidelines and a field guide are of the tools that were developed to help prevent spread of plants that could pose a large ecological threat.

Johnston, C. A., Zedler, J. B., Tulbure, M. G., Frieswyk, C. B., Bedford, B. L., & Vaccaro, L. (2009). A unifying approach for evaluating the condition of wetland plant communities and identifying related stressors. *Ecological Applications*, *19*(7), 1739-1757.

- An attempt to determine wetland health by taking into account human stressors, water depth, biological conditions, and geography was made. They employed CART models were employed for analysis.

Outridge, P. M., & Noller, B. N. (1991). Accumulation of toxic trace elements by freshwater vascular plants. In *Reviews of Environmental Contamination and Toxicology* (pp. 1-63). Springer New York.

- This study focused on the vascular fresh water plants and their significance as toxin removers due to higher concentrations of heavy metals being found in plant tissues than in the surrounding water.

Skubinna, J. P., Coon, T. G., & Batterson, T. R. (1995). Increased abundance and depth of submersed macrophytes in response to decreased turbidity in Saginaw Bay, Lake Huron. *Journal of Great Lakes Research*, *21*(4), 476-488.

- It was determined that the decrease in turbidity, due to the filtering activity of zebra mussels, can lead to the distribution and abundance of macrophytes to increase.

Stanley, K. E., Murphy, P. G., Prince, H. H., & Burton, T. M. (2005). Long-term ecological consequences of anthropogenic disturbance on Saginaw Bay coastal wet meadow vegetation. *Journal of Great Lakes Research*, *31*, 147-159.

- This study looked at the effect of long term human stressors on meadow plants. It was found that wet meadow vegetation, in particular, is hearty and can reestablish in disturbed areas. However, nuisance meadow vegetation, such as purple loosestrife, were more common in disturbed areas.

Wells, J. R., Kaufman, P. B., & Jones, J. D. (1980). Heavy metal contents in some macrophytes from Saginaw Bay (Lake Huron, USA). *Aquatic Botany*, *9*, 185-193.

- The analysis of 15 heavy metals in 22 different macrophyte species showed that the highest concentration of heavy metals were in the macrophytes closest to the Saginaw River mouth.

i. Phragmites

Kowalski, K. P., Bacon, C., Bickford, W., Braun, H., Clay, K., Leduc-Lapierre, M. & Wilcox, D. A. (2015). Advancing the science of microbial symbiosis to support invasive species management: A case study on *Phragmites* in the Great Lakes. *Frontiers In Microbiology*, *6*.

- This study addresses the relationship dynamics of invasive species with microorganisms and how these affect the native species. This knowledge could lead to more specialized invasive species management.

Mazur, C. The GLRI Phragmites Decision Support Tool Mapper. USGS.

- Different components and tools work together to create a map that gives insight into resource management by providing necessary information on *Phragmites*.

Mazur, M. L. C., Kowalski, K. P., & Galbraith, D. (2014). Assessment of suitable habitat for *Phragmites australis* (common reed) in the Great Lakes coastal zone. *Aquatic Invasions*, *9*(1), 1-19.

- Species distribution modeling was used to determine current areas invaded by *Phragmites* and to locate areas that could be colonized in the future based on climate, soil types, topography, and land use.

Saltonstall, K. (2002). Cryptic invasion by a non-native genotype of the common reed, *Phragmites australis*, into North America. *Proceedings of the National Academy of Sciences*, *99*(4), 2445-2449.

- Through DNA research, it has been found that the invasion of non-native *Phragmites* has overreached by expanding into areas that did not historically carry this plant and has outgrown the native species. This is concerning as the invasion in New England wiped out the native species.

Tulbure, M. G., & Johnston, C. A. (2010). Environmental conditions promoting non-native *Phragmites australis* expansion in Great Lakes coastal wetlands. *Wetlands, 30*(3), 577-587.

- Exposed soil and shallow water were the factors that attributed to the most invasive *Phragmites* growth. This is concerning because of decreasing water depths that may be exacerbated with climate change in the future.

Vymazal, J., Kröpfelová, L., Švehla, J., Chrastný, V., & Štíchová, J. (2009). Trace elements in *Phragmites australis* growing in constructed wetlands for treatment of municipal wastewater. *Ecological Engineering*, *35*(2), 303-309.

- The determination of element uptake by different parts of *Phragmites* in natural and constructed wetlands as it related to the wastewater treatment in the Czech Republic.

II. Invertebrates

a. Zooplankton

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

- It was determined by weight based filtering rate comparisons that the reduction in phytoplankton was not due to the zooplankton grazing.

Cole, R. A., & Weigmann, D. L. (1983). Relationships among zoo benthos, sediments, and organic matter in littoral zones of western Lake Erie and Saginaw Bay. *Journal of Great Lakes Research*, *9*(4), 568-581.

- The type of matter and particle size of the sediment had the greatest impact on diversity and distribution of zoo benthos, where macrophytes had less of an effect.

b. Macroinvertebrates

Bridgeman, T. B., Schloesser, D. W., & Krause, A. E. (2006). Recruitment of Hexagenia mayfly nymphs in western Lake Erie linked to environmental variability. *Ecological Applications*, *16*(2), 601-611.

- Stratification model for prediction, taking into consideration water temperature, wind speed, and data in the water column. The effect stratification will have on mayfly nymphs for Lake Erie was discussed.

Brinkhurst, R. O. (1967). The distribution of aquatic oligochaetes in Saginaw Bay, Lake Huron. *Limnology and Oceanography*, *12*(1), 137-143.

- This study looked for the correlation between physiochemical factors of oligochaetes and their relative distribution.

Burton, T. M., Uzarski, D. G., Gathman, J. P., Genet, J. A., Keas, B. E., & Stricker, C. A. (1999). Development of a preliminary invertebrate index of biotic integrity for Lake Huron coastal wetlands. *Wetlands*, *19*(4), 869-882.

- The development of IBI's was determined by comparison of biota from less polluted wetlands than those in the Saginaw Bay and 14 metrics were successful in determining the difference between impacted and not impacted sites.

Burton, T. M., Uzarski, D. G., & Genet, J. A. (2004). Invertebrate habitat use in relation to fetch and plant zonation in northern Lake Huron coastal wetlands. *Aquatic Ecosystem Health & Management*, *7*(2), 249-267.

- The effects of waves on plant and invertebrate community distribution were analyzed. It was found that there was no major difference seen in plant communities, but a conceptual model was proposed for the invertebrates.

Cooper, M. J. (2014). Research summary: Spatial and temporal trends in invertebrate communities of Great Lakes coastal wetlands. *Institute for Great Lakes Research and Department of Biology, Central Michigan University.*

- The goal of this study was to expand on the relationships and dynamics that are involved in the health, abundance, and diversity of macroinvertebrates in the Great Lakes Coastal wetlands.

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

- Community shifts correlated with changes in water depth greatly although other factors would have been influential as well.

Grigorovich, I. A., Kang, M., & Ciborowski, J. J. (2005). Colonization of the Laurentian Great Lakes by the amphipod *Gammarus tigrinus*, a native of the North American Atlantic coast. *Journal of Great Lakes Research*, *31*(3), 333-342.

- *G. tigrinus* is a non-native amphipod that is thriving in the Great Lakes.

Levri, E. P., Opiela, C., & Bilka, R. (2013). The invasive New Zealand mud snail (*Potamopyrgus antipodarum*) not detected in western Lakes Huron and St Clair. *Journal of the Pennsylvania Academy of Science, 814*(1), 10-15.

- This study was proactive in sampling populations in the Saginaw Bay to be sure that the invasive mud snail had not been introduced to Lake Huron.

Nalepa, T. F., Fanslow, D. L., Lansing, M. B. & Lang, G. A. (2003). Trends in the benthic macroinvertebrate community of Saginaw Bay, Lake Huron, 1987 to 1996: Responses to phosphorus abatement and the zebra mussel, *Dreissena polymorpha*. *Journal of Great Lakes Research, 29*(1), 14–33.

- Both the inner and the outer Saginaw Bay were observed for determining community trends. Distinct differences were found in each portion of the Bay and these differences were attributed to the changes that occurred post Dreissena.

Richards, C., Haro, R., Johnson, L., & Host, G. (1997). Catchment and reach-scale properties as indicators of macroinvertebrate species traits. *Freshwater Biology, 37*(1), 219-230.

- A strong correlation was found between traits of species and the physical habitat. Linear regression models showed some predictability of species. The reach-scale properties seemed to be more significant.

Richards, C., Host, G. E., & Arthur, J. W. (1993). Identification of predominant environmental factors structuring stream macroinvertebrate communities within a large agricultural catchment. *Freshwater Biology*, *29*(2), 285-294.

- This analysis showed the importance of substrate characteristics in macroinvertebrate communities although many habitat conditions were monitored.

Richards, C., Johnson, L. B., & Host, G. E. (1996). Landscape-scale influences on stream habitats and biota. *Canadian Journal of Fisheries and Aquatic Sciences*, *53*(S1), 295-311.

- This study showed that the effects of land use and the geological features have near equivalent impacts on the health of streams.

Schloesser, D. W., Robbins, J. A., Matisoff, G., Nalepa, T. F., & Morehead, N. R. (2014). A 200 year chronology of burrowing mayflies (*Hexagenia* spp.) in Saginaw Bay. *Journal of Great Lakes Research*, *40*(1), 80-91.

- Based on historical records and data it was determined that mayflies were native in the Saginaw Bay and that the eutrophication of the bay caused a decline.

Additionally, it was found that there is a possibility for recovery of the mayflies if the proper conditions are met to support the growth of nymphs.

Schneider, J. C., Hooper, F. F., & Beeton, A. M. (1969). The distribution and abundance of benthic fauna in Saginaw Bay, Lake Huron. In *Proceedings of the 12th Conference on Great Lakes Research*, 80-90.

Siersma, H. M., Foley, C. J., Nowicki, C. J., Qian, S. S., & Kashian, D. R. (2014). Trends in the distribution and abundance of *Hexagenia* spp. in Saginaw Bay, Lake Huron, 1954–2012: Moving towards recovery? *Journal of Great Lakes Research*, *40*, 156-167.

- After sampling both mayfly adults and nymphs at different sites in the Bay and finding the composition of sediments through modeling, it was found that the *Hexagenia* population is beginning to recover in the Saginaw Bay.

Uzarski, D. G., Burton, T. M., & Genet, J. A. (2004). Validation and performance of an invertebrate index of biotic integrity for Lakes Huron and Michigan fringing wetlands during a period of lake level decline. *Aquatic Ecosystem Health & Management*, *7*(2), 269-288.

- This invertebrate IBI was developed with differing water levels and wave fluctuations in mind. Spatial and temporal variations in sites were tested using the index with what was reported as satisfactory results pointing to use and implementation of this index.

i. <u>Dreissena</u>

Bierman Jr, V. J., Dilks, D. W., Feist, T. J., DePinto, J. V., & Kreis Jr, R. G. (1998). Coupled phytoplankton-zebra mussel model for Saginaw Bay, Lake Huron. In *Proceedings of Workshop on Aquatic Ecosystem Modeling and Assessment Techniques for Application within the US Army Corps of Engineers, Paper No. EL98-1, US Army Engineer Waterways Experiment Station*, 43-67.

- Improvement of existing models, USCAE, and development of new models for ecosystem restoration.

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

- Post-zebra mussel invasion, *Microcystis* blooms inhabited the area. This study employed models to develop a baseline for pre-invasion conditions and attributed the *Microcystis* blooms to the selective avoidance of it by the zebra mussels and the increases in phosphorus cycling due to zebra mussel populations.

Budd, J. W., Drummer, T. D., Nalepa, T. F., & Fahnenstiel, G. L. (2001). Remote sensing of biotic effects: Zebra mussels (*Dreissena polymorpha)* influence on water clarity in Saginaw Bay, Lake Huron. *Limnology and Oceanography*, *46*(2), 213-223.

- AVHRR was used to capture images that allowed the reflectance to be seen and to determine differences in water quality pre and post *Dreissena* colonization. Regression models were used; SeaWiFs and MODIS are possibilities that can monitor future reflectance change that can occur in areas of high *Dreissena* density (turbidity changes also occur seasonally).

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

- Comparison of water nutrients, algae, and *Microcystis* in microcosms with and without zebra mussels. Shifts in nitrogen and phosphorus in the water, as well as possible selective feeding were attributed as causes of *Microcystis* blooms in zebra mussel inhabited waters.

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

- Two different species of mussel were addressed: the quick near shore colonizing zebra mussels and the slower offshore quagga mussels. Mass balance models show high percentages of phosphorus retention by mussels which could attribute to the reduction of other species such as *Diporeia*.

Cotner, J. B., Gardner, W. S., Johnson, J. R., Sada, R. H., Cavaletto, J. F., & Heath, R. T. (1995). Effects of zebra mussels (*Dreissena polymorpha*) on bacterioplankton: Evidence for both size-selective consumption and growth stimulation. *Journal of Great Lakes Research, 21*(4), 517-528.

- Different effects were observed when monitoring zebra mussel bacterial selection between the inner and outer Saginaw Bay.

Fahnenstiel, G. L., Lang, G. A., Nalepa, T. F., & Johengen, T. H. (1995). Effects of zebra mussel (*Dreissena polymorpha*) colonization on water quality parameters in Saginaw Bay, Lake Huron. *Journal of Great Lakes Research*, *21*(4), 435-448.

- In areas with a large number of zebra mussels (primarily the inner Bay), it was found that chlorophyll and total phosphorus decreased, while Secchi depth increased which showed a spatial change in water quality.

Fanslow, D. L., Nalepa, T. F., & Johengen, T. H. (2001). Seasonal changes in the respiratory electron transport system (ETS) and respiration of the zebra mussel, *Dreissena polymorpha* in Saginaw Bay, Lake Huron. *Hydrobiologia*, *448*(1-3), 61-70.

- ETS was found to be higher in the outer Bay and was contributed to higher quality of food. Also, ETS and respiration varied with temperature. It was indicated that these units of measurement maybe better suited for long term study.

Fanslow, D. L., Nalepa, T. F., & Lang, G. A. (1995). Filtration rates of the zebra mussel (*Dreissena polymorpha*) on natural seston from Saginaw Bay, Lake Huron. *Journal of Great Lakes Research*, *21*(4), 489-500.

- Filtration rates were measured from the inner and outer Bay. A relationship between filtration rate and temperature was observed. In 1992, it was found that the inner bay filtration rates were lower than in the outer bay.

Fishman, D. (2008). A statistical and dynamic modeling analysis of phytoplankton changes in Saginaw Bay, Lake Huron during the zebra mussel invasion. *University of Michigan, Doctoral dissertation.*

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

- The effects of zebra mussels are clearer waters (less turbidity), phosphorus cycling, and the rejection of *Microcystis* that leads to blooms.

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

- This study proved that zebra mussels alter the phytoplankton community by filtration, nutrient cycling, and by altering overall water quality, all of which change the depth to which light penetrates through the water.

Francoeur, S. N., Pillsbury, R. W., & Lowe, R. L. (2015). Benthic algal response to invasive mussels in Saginaw Bay: A comparison of historical and recent data. *Journal of Freshwater Ecology*, (ahead-of-print), 1-15.

- Algal growth was found to be phosphorus limited. Also, it was found that various changes occurred throughout the year and was attributed to water clarity as affected by mussel filtration.

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

- This study showed increases in SRP and decreases in algae and chlorophyll, as well as decreased turbidity that accompanies a greater abundance of zebra mussels. The research results proved that there are increases in the clarity of water, as well as changes in water quality parameters in areas with large numbers of mussels.

James, W. F., Barko, J. W., & Eakin, H. L. (1997). Nutrient regeneration by the zebra mussel (*Dreissena polymorpha). Journal of Freshwater Ecology*, *12*(2), 209-216.

- This study set out to determine the nutrient cycling that occurs as the result of zebra mussel filtration. Total suspended solids and chlorophyll were shown to be removed at greater than 70% from the water. Increases in nutrient cycling were observed for nitrogen and phosphorus.

Johengen, T. H., Nalepa, T. F., Fahnenstiel, G. L., & Goudy, G. (1995). Nutrient changes in Saginaw Bay, Lake Huron, after the establishment of the zebra mussel (*Dreissena polymorpha*). *Journal of Great Lakes Research*, *21*(4), 449-464.

- Analysis of water contents between the years pre- and post-zebra mussels shows reduction in contents suspended in the water. Studies of water parameters pointed to zebra mussels being a sink for phosphorus.

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

- This study showed significant alterations in the composition of phytoplankton and protozoa as a result of high zebra mussel density.

Lowe, R.L, and R.W. Pillsbury. Shifts in benthic algal community structure and function following the appearance of zebra mussels (*Dreissena polymorpha*) in Saginaw Bay, Lake Huron. J. Great Lakes Res., 21 (1995), pp. 558–566.

- Zebra mussels filter water for their food sources, thereby lowering turbidity and allowing more light to reach benthic algae. This research concluded that filtering allows for increased rates in photosynthesis and the ability of larger algae such as filamentous algae to dominate the previously common phytoplankton community of diatoms.

MacIsaac, H. J. (1996). Potential abiotic and biotic impacts of zebra mussels on the inland waters of North America. *American Zoologist*, *36*(3), 287-299.

- Water quality is dramatically altered by the filtering activity of zebra mussels. Filtration leads to the reduction of plankton and suspended solids, which allows

for decreases in turbidity, consequently allowing an increase in photosynthetic productivity of plants.

Nalepa, T. F., & Fahnenstiel, G. L. (1995). *Dreissena polymorpha* in the Saginaw Bay, Lake Huron ecosystem: Overview and perspective. *Journal of Great Lakes Research*, *21*(4), 411-416.

Nalepa, T. F., Fahnenstiel, G. L., & Johengen, T. H. (1999). Impacts of the zebra mussel (*Dreissena polymorpha*) on water quality: A case study in Saginaw Bay, Lake Huron. *Nonindigenous Freshwater Organisms*, 255-271.

Nalepa, T. F., Fahnenstiel, G. L., McCormick, M. J., Johengen, T. H., Lang, G. A., Cavaletto, J. F., & Goudy, G. (1996). Physical and chemical variables of Saginaw Bay, Lake Huron in 1991-93. *NOAA Technical Memorandum ERL GLERL*, (91).

- This was a monitoring effort in the Saginaw Bay to determine physical and chemical variables in response to the zebra mussel invasion.

Nalepa, T. F., Wojcik, J. A., Fanslow, D. L., & Lang, G. A. (1995). Initial colonization of the zebra mussel (*Dreissena polymorpha*) in Saginaw Bay, Lake Huron: Population recruitment, density, and size structure. *Journal of Great Lakes Research*, *21*(4), 417-434.

- After looking at densities of larvae, juveniles, and adults it was uncertain if the population could be at equilibrium or not. Relationships between these life stages and density were not observed with a definitive trend.

Nicholls, K. H., Hopkins, G. J., & Standke, S. J. (1999). Reduced chlorophyll to phosphorus ratios in nearshore Great Lakes waters coincide with the establishment of dreissenid mussels. *Canadian Journal of Fisheries and Aquatic Sciences*, *56*(1), 153-161.

- Spatial and temporal variance in the chlorophyll to phosphorus ratios were seen throughout different areas of the Great Lakes.

Perry, W. L., Lodge, D. M., & Lamberti, G. A. (2000). Crayfish (*Orconectes rusticus*) impacts on zebra mussel (*Dreissena polymorpha*) recruitment, other macroinvertebrates and algal biomass in a lake-outlet stream. *The American Midland Naturalist*, *144*(2), 308-316.

- Controlled studies showed that a high abundance of rusty crayfish decreases the abundance of zebra mussels and macroalgae.

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

- Dissolved phosphorus was found to be decreased during the experiment. Through the nutrient manipulation experiment additions of phosphorus increased chlorophyll where nitrogen did not have a noticeable effect, but the increase in water clarity from the mussels seemed to have the greatest effect. This study suggests a new ecological equilibrium.

Stewart, T. W., Miner, J. G., & Lowe, R. L. (1998). An experimental analysis of crayfish (*Orconectes rusticus*) effects on a Dreissena-dominated benthic macroinvertebrate community in western Lake Erie. *Canadian Journal of Fisheries and Aquatic Sciences*, *55*(4), 1043-1050.

- This study found that rusty crayfish did not reduce the abundance of *Dreissena* but did reduce other invertebrates in Lake Erie.

Strayer, D. L., Caraco, N. F., Cole, J. J., Findlay, S., & Pace, M. L. (1999). Transformation of freshwater ecosystems by bivalves. *BioScience*, *49*(1), 19-27.

- Focused study on the Hudson River ecosystem and the niche that clams and mussels fill.

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

- The selectivity of the different species of mussels showed some importance. Both quagga and zebra mussels filter feed similar sizes but have differing rates of filtration and reasons for differences are given.

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

- Different mechanisms of feeding behavior were studied at sites in the Saginaw Bay and Lake Erie for comparison.

Vanderploeg, H. A., Liebig, J. R., Carmichael, W. W., Agy, M. A., Johengen, T. H., Fahnenstiel, G. L., & Nalepa, T. F. (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), 1208-1221.

- *Microcystis aeruginosa* was proven to be rejected by zebra mussels, which contributes to the overfeeding of other algae while allowing harmful blooms.

Wilson, A. E., & Sarnelle, O. (2002). Relationship between zebra mussel biomass and total phosphorus in European and North American lakes. *Archive of Hydrobiology*, *153*(2), 339-351.

- Regression models were developed to predict the biomass of zebra mussels with respect to phosphorus water levels.

ii. Diporeia

Gossiaux, D. C., Landrum, P. F., & Tsymbal, V. N. (1993). A survey of Saginaw River and Saginaw Bay, Lake Huron, sediments using two bioassays with the amphipod *Diporeia* spp. *Journal of Great Lakes Research*, *19*(2), 322-332.

- Solid phase bioassays of *Diporeia* were used as an indicator of water health based on sediment preferences and mortality. Sediments were taken from various locations in the Bay and river and mouth regions. The site for Tawas Bay was found to be the most toxic to *Diporeia*, it was the most preferred sediment, and had the highest mortality. The site near the Bay City Water Treatment plant was found to have the highest mortality in December of 1989. The results indicated contamination in the Saginaw River and Bay.

Nalepa, T. F., Fanslow, D. L., & Lang, G. A. (2009). Transformation of the offshore benthic community in Lake Michigan: Recent shift from the native amphipod *Diporeia* spp. to the invasive mussel *Dreissena rostriformis bugensis*. *Freshwater Biology*, *54*(3), 466-479.

- The invasive *Dreissena* has replaced *Diporeia* and therefore has made the benthic community less able to supply the upper trophic levels with energy as it had in the past. Reasons for this were not well known.

Nalepa, T. F., Fanslow, D. L., & Messick, G. (2005). Characteristics and potential causes of declining *Diporeia* spp. populations in southern Lake Michigan and Saginaw Bay, Lake Huron.

- Despite the proposed theory that the decline of *Diporeia* is due to out competition of food supply by *Dreissena*, there was no evidence to support of starvation in the species. Additionally, at some sites, near zero densities of *Diporeia* were found where *Dreissena* were not present.

Palmer, M. A., & Covich, A. P. Michigan. Journal of Great Lakes Research 27: 384-391. Nalepa TF, Fanslow DL, Messick G. 2005. Characteristics and potential causes of declining *Diporeia* spp. populations in southern Lake Michigan and Saginaw Bay, Lake Huron. In: Proceedings of a workshop on the dynamics of lake whitefish (*Coregonus clupeaformis*). *Wildlife Diseases*, *40*(3), 414-419.

- Competition for food was not the causative factor for *Diporeia* decline post zebra mussel invasion. The adequate lipid content and no signs of starvation point to other causes for the decline of *Diporeia*.

III. Vertebrates

a. Fish

Baker, E. A. 2006. Lake sturgeon distribution and status in Michigan, 1996–2005. *Michigan Department of Natural Resources, Fisheries Technical Report* 2006-4, Ann Arbor.

- Threatened lake sturgeon were found to occupy sand, silt, and sand/gravel areas of rivers in their early stages of life. This study also gave locations of populations, as well as predictions of reproduction. This information can help rehabilitation efforts.

Bence, J. R., & Mohr, L. C. (2008). State of Lake Huron: Current and future. *The State of Lake Huron in 2004*, 71-75.

- The shifts in fish community abundance and relationships have continued to change and are projected to continue although the complete cause of the changes in predator prey dynamics are not fully understood.

Blouzdis, C. E., Ivan, L. N., Pothoven, S. A., Roswell, C. R., Foley, C. J., & Höök, T. O. (2013). A trophic bottleneck?: The ecological role of trout-perch *Percopsis omiscomaycus* in Saginaw Bay, Lake Huron. *Journal of Applied Ichthyology*, *29*(2), 416-424.

- Trout-perch were found to have a similar diet as young walleye and yellow perch. It was found that trout-perch were not common prey for higher trophic levels of fish.

Burnham, K. P., Anderson, D. R., White, G. C., Brownie, C., & Pollock, K. H. (1988). Design and analysis methods for fish survival experiments based on release-recapture. *Journal of Applied Ecology*.

Colby, P. J., Spangler, G. R., Hurley, D. A., & McCombie, A. M. (1972). Effects of eutrophication on salmonid communities in oligotrophic lakes. *Journal of the Fisheries Board of Canada*, *29*(6), 975-983.

- The changes in water quality brought on by eutrophication can have temporally different effects on fish communities by initially increasing in size before having developmental and reproductive issues that hinder survival.

Cooper, M. J., Ruetz III, C. R., Uzarski, D. G., & Shafer, B. M. (2009). Habitat use and diet of the round goby (*Neogobius melanostomus*) in coastal areas of Lake Michigan and Lake Huron. *Journal of Freshwater Ecology*, *24*(3), 477-488.

- The non-native goby was not found to correlate with the location of mussels and had a varied spatial distribution and their diet consisted mainly of zooplankton and two-winged insects.

Coscarelli, M. A. (2006). Enhancing fish passage over low-head barrier dams in the Saginaw River watershed. *Doctoral dissertation, Michigan State University.*

Diana, J. S., & Salz, R. (1990). Energy storage, growth, and maturation of yellow perch from different locations in Saginaw Bay, Michigan. *Transactions of the American Fisheries Society, 119*(6), 976-984.

- Data showed that the growth of yellow perch in Saginaw Bay was poor, potentially due to inability to build up energy reserves. Behavioral differences were given as a cause for the variability in age distributions between the inner and outer bay.

Doran, P. J. (2012). Protecting fish from agricultural impacts as climate changes: How much conservation is enough? *AFS 142nd Annual Meeting*.

- The SWAT model was used to determine the effects of climate change on current ecological stressors and the success that conservation practices could provide in forecasting future needs.

Echols, K. R., Gale, R. W., Schwartz, T. R., Huckins, J. N., Williams, L. L., Meadows, J. C., Morse, D., Petty, J. D., Orazio, C. E. & Tillitt, D. E. (2000). Comparing polychlorinated biphenyl concentrations and patterns in the Saginaw River using sediment, caged fish, and semipermeable membrane devices. *Environmental Science & Technology*, *34*(19), 4095-4102.

- Different techniques were employed to determine PCB concentrations in order to give an overall view of the contamination in aquatic life, in the water, and in the sediments, as the concentrations that were found varied.

El-Zarka, S. E. D. (1959). Fluctuations in the population of yellow *Perca flavescens* (Mitchill) in Saginaw Bay Lake Huron. *Fisheries*, *1*, 28.

- Determination of sex ratios, length, and weight in yellow perch. This study also looked at growth rate, size, and age distributions.

Eshenroder, R. L. (1977). Effects of intensified fishing, species changes, and spring water temperatures on yellow perch, *Perca flavescens*, in Saginaw Bay. *Journal of the Fisheries Board of Canada*, *34*(10), 1830-1838.

- Spring temperature was determined to have a large impact on the success of reproduction. The changes in fish populations, such as walleye and alewives, also had an effect and growth rate increased with the fishery intensification.

Fielder, D. G. (2002). Sources of walleye recruitment in Saginaw Bay, Lake Huron. *North American Journal of Fisheries Management*, *22*(3), 1032-1040.

- It was found that the spawning reefs in the Saginaw Bay were not widely used by walleye. The population consists of wild fish and mostly of hatchery fish.

Fielder, D. G. (2004). Increasing predation through walleye fingerlings stocking: A recovery tool for Saginaw Bay, Lake Huron. In *Propagated Fish in Resource Management. American Fisheries Society Symposium*, *44*, 105-112.

Fielder, D. G., & Baker, J. P. (2004). Strategy and options for completing the recovery of walleye in Saginaw Bay, Lake Huron. *Michigan Department of Natural Resources, Fisheries* Special Report 29, Ann Arbor.

- MDNR discusses research and current recovery goals. Recovery goals include self-sustainability, carrying capacities, predator-prey relations for the walleye population, and ecological balances.

Fielder, D. G., Johnson, J. E., Weber, J. R., Thomas, M. V., & Haas, R. C. (2000). *Fish Population Survey of Saginaw Bay, Lake Huron, 1989-97*. Michigan Department of Natural Resources, Fisheries Division.

- A fish community survey was conducted including yellow perch and walleye. Yellow perch were found to have improved growth and lower density and the walleye had years of low recruitment which coincided with absence of stocking. Zebra mussels were not pinpointed as a cause of distribution changes.

Fielder, D. G., Schaeffer, J. S., & Thomas, M. V. (2007). Environmental and ecological conditions surrounding the production of large year classes of walleye (*Sander vitreus*) in Saginaw Bay, Lake Huron. *Journal of Great Lakes Research*, *33*, 118-132.

- Development of Ricker-stock recruitment models to account for factors that affect reproductive success of the walleye population. It was found that alewives were a major factor but not the only one.

Fielder, D. G., & Thomas, M. V. (2006). *Fish Population Dynamics of Saginaw Bay, Lake Huron, 1998-2004*. Michigan Department of Natural Resources, Fisheries Division.

- Reduction of adult alewives appears to be positively affecting the overall fish population with an increase in walleye documented.

Gale, R. W., Huckins, J. N., Petty, J. D., Peterman, P. H., Williams, L. L., Morse, D., Schwartz, T. R. & Tillitt, D. E. (1996). Comparison of the uptake of dioxin-like compounds by caged channel catfish and semipermeable membrane devices in the Saginaw River, Michigan. *Environmental Science & Technology*, *31*(1), 178-187.

- This study attempted to determine the bioavailability of halogenated hydrocarbons for fish.

Giesy, J. P., Jude, D. J., Tillitt, D. E., Gale, R. W., Meadows, J. C., Zajieck, J. L., Peterman, P.H., Verbrugge, D.A., Sanderson, J.T., Schwartz, T.R., & Tuchman, M. L. (1997). Polychlorinated dibenzo-p-dioxins, dibenzofurans, biphenyls and 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin equivalents in fishes from Saginaw Bay, Michigan. *Environmental Toxicology and Chemistry*, *16*(4), 713-724.

- Significant concentrations were not found when looking at carp, walleye, and alewives.

Giesy, J. P., & Kannan, K. (2001). Global distribution of perfluorooctane sulfonate in wildlife. *Environmental Science & Technology*, *35*(7), 1339-1342.

- Collection of samples from different species throughout the Arctic and North America, and especially the Great Lakes, were obtained to determine the concentration of perfluorooctane sulfonate (PFOS). PFOS were found to bioaccumulate in higher trophic levels. The greatest concentrations were found in urbanized areas and the Great Lakes.

Gordon, W. G. (1961). Food of the American smelt in Saginaw Bay, Lake Huron. *Transactions of the American Fisheries Society*, *90*(4), 439-443.

- It was found that the major food eaten by smelt consisted of crustaceans, insects, and fish eggs. The majority of insects eaten were mayflies.

Hile, R. O. (1954). *Fluctuations in growth and year-class strength of the walleye in Saginaw Bay*. US Government Printing Office.

- This survey of walleye gives information of the sex ratio, length, weight, and age of the population in the Saginaw Bay.

Ivan, L. N., Höök, T. O., Thomas, M. V., & Fielder, D. G. (2011). Long-term and interannual dynamics of walleye and yellow perch in Saginaw Bay, Lake Huron. *Transactions of the American Fisheries Society*, *140*(4), 1078-1092.

- This study was conducted to determine the overall trends in the populations of walleye and yellow perch and they were found to have different trends.

Jude, D. J., Rediske, R., O'Keefe, J., Hensler, S., & Giesy, J. P. (2010). PCB concentrations in walleyes and their prey from the Saginaw River, Lake Huron: A comparison between 1990 and 2007. *Journal of Great Lakes Research*, *36*(2), 267-276.

- This study was conducted to determine the PCB concentrations in walleye from 2007 and compare them with the data from 1990.

Kowalski, A., Zollweg, E., & Hill, T. (2002). Lake sturgeon status survey in Saginaw Bay of Lake Huron as reported by commercial fishers.

Madel, G. (2013). The influence of trophic guild composition on the body size distributions and trophic structure of mid-order river fish communities. *143rd Annual Meeting of the American Fisheries Society*.

- Food web dynamics and insight into the fish community composition in rivers was determined through various analyses.

Madenjian, C. P., Trombka, A. W., Rediske, R. R., Jude, D. J., & O'Keefe, J. P. (2012). Sex difference in polybrominated diphenyl ether concentrations of walleyes. *Journal of Great Lakes Research*, *38*(1), 167-175.

- The difference in PBDE concentration between the sexes was attributed to females spending less time in the Saginaw River than the males, which had higher PBDE concentrations.

Manny, B. A., Jude, D. J., & Eshenroder, R. L. (1989). Field test of a bioassay procedure for assessing habitat quality on fish spawning grounds. *Transactions of the American Fisheries Society*, *118*(2), 175-182.

- This study showed that lake trout eggs that remained buried in the substrate had a higher rate of hatching than those that were not adequately buried in the spawning substrate.

Roseman, E. F., Schaeffer, J. S., & Steen, P. J. (2009). Review of fish diversity in the Lake Huron basin. *Aquatic Ecosystem Health & Management*, *12*(1), 11-22.

- An overview of fish species diversity and the interaction of these species and their environment with the goal to aide in presenting information to be used for conservation efforts. It reports that of the 129 species of the 1970s, 20 species have been destroyed or are extremely at risk.

Sepulveda-Villet, O. J., & Stepien, C. A. (2012). Waterscape genetics of the yellow perch (*Perca flavescens*): Patterns across large connected ecosystems and isolated relict populations. *Molecular Ecology*, *21*(23), 5795-5826.

- The analysis of DNA sequences of yellow perch to determine the genetic divergence/diversity could help give insight into the success of the species in the future.

Sesterhenn, T. M., Roswell, C. R., Stein, S. R., Klaver, P., Verhamme, E., Pothoven, S. A., & Höök, T. O. (2014). Modeling the implications of multiple hatching sites for larval dynamics in the resurgent Saginaw Bay walleye population. *Journal of Great Lakes Research*, *40*, 113-122.

- A combination of hydrodynamics, particle transport, and bioenergetics models were used to assess successful hatching sites for walleye in the Saginaw Bay.

Schaeffer, J. S., Diana, J. S., & Haas, R. C. (2000). Effects of long-term changes in the benthic community on yellow perch in Saginaw Bay, Lake Huron. *Journal of Great Lakes Research*, *26*(3), 340-351.

- The condition of the Saginaw Bay had lowered the abundance of the benthic community especially mayflies and this affected yellow perch composition which had a high natural death rate. Energetic models were employed and suggested that the food supply of yellow perch was limited.

Stepien, C. A., Murphy, D. J., Lohner, R. N., Sepulveda-Villet, O. J., & Haponski, A. E. (2009). Signatures of vicariance, postglacial dispersal and spawning philopatry: Population genetics of the walleye *Sander vitreus*. *Molecular Ecology*, *18*(16), 3411-3428.

Stoller, J. B. (2013). Effects of a rock ramp structure on summer fish assemblage in the Shiawassee River. *Doctoral dissertation, Michigan State University*.

- This study showed genetic barriers in the Great Lakes; the preservation of genetic integrity should be included in conservation of walleye.

Tharratt, R. C. (1959). Food of yellow perch, *Perca flavescens* (Mitchill) in Saginaw Bay, Lake Huron. *Transactions of the American Fisheries Society*, *88*(4), 330-331.

- This study showed that yellow perch were primarily eating immature insects, such as larvae, pupae, and nymphs.

Thompson, K. F. (2004). Evaluation of partners for fish and wildlife wetland restoration efforts in the Saginaw Bay Watershed. *Doctoral dissertation, Michigan State University. Department of Fisheries and Wildlife.*

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

- Water quality parameters were tested to determine concentrations and correlations between the parameters and the sample sites. It was found that phosphorus was able to be mobilized in wetlands that had low DO and low pH. Higher levels of phosphorus were found in these hypoxic areas.

Zollweg, E. C., Gunderman, B. J., Elliott, R. F., Kowalski, A. Hill, T. D., & Miller, G. (2003). Lake sturgeon assessment assistance by Great Lakes commercial fishers.

- The involvement of commercial fishers partnering with biologist to collect data, report on, and tag lake sturgeon is helping this threatened species.

i. Fish Diseases

Getchell, R. G., Culligan, W. J., Kirchgessner, M., Sutton, C. A., Casey, R. N., & Bowser, P. R. (2006). Quantitative polymerase chain reaction assay used to measure the prevalence of *Clostridium botulinum* type E in fish in the lower Great Lakes. *Journal of Aquatic Animal Health*, *18*(1), 39-50.

- Fish at the point of death were examined and found to carry *C. botulinum.* This has implication for live fish eating birds. Fish that were healthy and recently dead were also examined and had evidence of *C. botulinum*.

Riley, S. C., Munkittrick, K. R., Evans, A. N., & Krueger, C. C. (2008). Understanding the ecology of disease in Great Lakes fish populations. *Aquatic Ecosystem Health & Management*, *11*(3), 321-334.

- Key components of disease such as botulism, bacterial kidney disease, and thiamine deficiency complex were addressed. A population-level research dynamic looks at ecological factors in relation in order to disease to attempt to have some predictability as to how disease affects fish and the ecosystem.

Riley, S. C., Roseman, E. F., Nichols, S. J., O'Brien, T. P., Kiley, C. S., & Schaeffer, J. S. (2008). Deepwater demersal fish community collapse in Lake Huron. *Transactions of the American Fisheries Society*, *137*(6), 1879-1890.

- Decreases in abundance were found in this bottom dwelling fish survey and were as high as 99% for common fish species of Lake Huron over the 1974-2006 timespan. Temporal separation was used for distinction of early and late sampling times.

Madenjian, C. P., Jude, D. J., Rediske, R. R., O'Keefe, J. P., & Noguchi, G. E. (2009). Gender difference in walleye PCB concentrations persists following remedial dredging. *Journal of Great Lakes Research*, *35*(3), 347-352.

- The males had a higher ratio of PCB concentration in comparison to females, which was attributed to differences in habitat use and prey consumption. However, in this study it was found that the dredging and removal of contaminated sediment drastically reduced the percentage of PCB concentration in both genders as observed in a ten year period.

b. Herpetofauna

Burton, T. M., & Uzarski, D. G. (2009). Biodiversity in protected coastal wetlands along the west coast of Lake Huron. *Aquatic Ecosystem Health & Management*, *12*(1), 63-76.

- This was a compilation of data from various sources to determine the species richness in the wetlands of Lake Huron. They estimate that there are about 10 species of frogs and toads and about 7 types of salamanders. The reptiles (about 20 species with no lizards) were estimated at over 10 different species of turtles and snakes each. It was mentioned that data was lacking for the herpetofauna.

Crewe, T. L., & Timmermans, S. T. (2005). Assessing biological integrity of Great Lakes coastal wetlands using marsh bird and amphibian communities. *Project# WETLAND3-EPA-01 Technical Report. Bird Studies Canada. Canada*.

- Spatial scales of bird and amphibian IBI's with disturbance gradients were developed to determine the overall condition of wetlands. Included were ways to improve the IBI's.

Ellis, M. M. (1917). Amphibians and reptiles of the Douglas Lake (Michigan) Region. *Ann. Rep. Mich. Acad. Sci*, *19*, 45-63.

- Updates to the list of herpetofauna of Northern Michigan were made through efforts at different collecting stations.

Glennemeier, K. A., & Begnoche, L. J. (2002). Impact of organochlorine contamination on amphibian populations in southwestern Michigan. *Journal of Herpetology*, *36*(2), 233-244.

- Determination of the effects of PCB on amphibians was carried out by comparing those living in known contaminated habitats to those that were not. Differences in population density were not found although negative effects to amphibians were found when treated with PCB in the lab during early life stages.

Hecnar, S. J. (1998). Effects of human disturbance on five-lined skink, *Eumeces fasciatus*, abundance and distribution. *Biological Conservation*, *85*(3), 213-222.

- A study to determine the effects of anthropogenic stress on lizards in Canada found that the removal of suitable habitats – large woody decaying materials such as logs – was the main cause of lowered skink abundance, not just high traffic of humans.

Mifsud, D. A. (2014). A status assessment and review of the herpetofauna within the Saginaw Bay of Lake Huron. *Journal of Great Lakes Research*, *40*, 183-191.

- This study observed 25 herpetofauna species and also found correlation with the invasive species *Phragmites*; the areas containing *Phragmites* did not have any notable amount of species and removal of this invasive could increase species abundance.

Ruthven, A. G. (1911). *A biological survey of the sand dune region on the south shore of Saginaw Bay, Michigan* (No. 2). Wynkoop, Hallenbeck, Crawford Company, state printers.

- Extensive research in topography, habitat, flora and fauna.

Wilcox, D. A., Meeker, J. E., Hudson, P. L., Armitage, B. J., Black, M. G., & Uzarski, D. G. (2002). Hydrologic variability and the application of index of biotic integrity metrics to wetlands: A Great Lakes evaluation. *Wetlands*, *22*(3), 588-615.

- IBI's are used as measurements for the determination of wetland conditions. However, variability can play a role when it is difficult to find comparable sites and when water levels change. This can be especially true for herpetofauna IBI's that may change drastically in comparison to avian IBI's if water levels change.

c. Avian

Bishop, C. A., Koster, M. D., Chek, A. A., Hussell, D. J., & Jock, K. (1995). Chlorinated hydrocarbons and mercury in sediments, red-winged blackbirds (*Agelaius phoeniceus*) and tree swallows (*Tachycineta bicolor*) from wetlands in the Great Lakes–St. Lawrence River Basin. *Environmental Toxicology and Chemistry*, *14*(3), 491-501.

- It was determined that although there was a correlation between the toxicity in red-winged black birds and concentrations in sediment, it was suggested that tree swallows would be a better indicator of bioaccumulation based on location.

Chen, D., Letcher, R. J., Gauthier, L. T., Chu, S., McCrindle, R., & Potter, D. (2011). Novel methoxylated polybrominated diphenoxybenzene congeners and possible sources in herring gull eggs from the Laurentian Great Lakes of North America. *Environmental Science & Technology*, *45*(22), 9523.

- This study determined the structure of six previously unidentified brominated substances in the eggs of herring gulls from the Great Lakes.

Courtney, P. A., & Blokpoel, H. (1980). Food and indicators of food availability for common terns on the lower Great Lakes. *Canadian Journal of Zoology*, *58*(7), 1318-1323.

- This study looked at chick growth, foraging time, and fish acceptance of common terns.

Fox, G. A., Trudeau, S., Won, H., & Grasman, K. A. (1998). Monitoring the elimination of persistent toxic substances from the Great Lakes; chemical and physiological evidence from adult herring gulls. In *Trends in Levels and Effects of Persistent Toxic Substances in the Great Lakes* (pp. 147-168). Springer Netherlands.

- Between 1974-1993, samples were taken to determine the persistence of PCB and similar toxins in herring gulls; it was found that the toxic substances were persistent throughout the study. In the 1990's, Saginaw Bay had the highest PCB concentrations found in the gulls sampled.

Froese, K. L., Verbrugge, D. A., Ankley, G. T., Niemi, G. J., Larsen, C. P., & Giesy, J. P. (1998). Bioaccumulation of polychlorinated biphenyls from sediments to aquatic insects and tree swallow eggs and nestlings in Saginaw Bay, Michigan, USA. *Environmental Toxicology and Chemistry*, *17*(3), 484-492.

- Based on the derived biota-sediment accumulation factor, the concentration of PCB toxins in the sediment of the Saginaw Bay should not be great enough to cause harmful effects to the swallows sampled.

Gamble, K., Hansen, F. J., Montana Fish, W., & Huang, P. M. (2007). A management plan for the eastern population of tundra swans.

- A management plan was proposed for the population of tundra swans and looked at population dynamics, habitat availability, and socioeconomic issues to determine the best management plan.

Gehring, J., & Leader, S. C. S. Z. (2011). Breeding bird research for the crosswinds wind energy site: Summary of fall migration 2011 field season.

- The Michigan State document prepared for Consumers Energy for the maximization of effectiveness of wind energy while minimizing the negative impact it can have for bird populations resulted in the best locations for turbines being in the regions that were predominantly agricultural fields.

Giesy, J. P., Ludwig, J. P., & Tillitt, D. E. (1994). Deformities in birds of the Great Lakes region. *Environmental Science & Technology, 28*(3), 128A-135A.

- The complications regarding the study of wildlife toxicology were discussed. Focus was given to chemicals, such as PCB's and DDT, in the environment due

to human action and the effect that they have on bird deformities and reproductive issues.

Gilbertson, M., Kubiak, T., Ludwig, J., & Fox, G. (1991). Great lakes embryo mortality, edema, and deformities syndrome (GLEMEDS) in colonial fish-eating birds: Similarity to chick-edema disease. *Journal of Toxicology and Environmental Health, Part A Current Issues, 33*(4), 455-520.

- GLEMEDS is found in many different avian species in the Great Lakes. It was found that this is similar to chick-edema disease which involves cytochrome p-448. The common signs of these diseases can be caused by furans, DDT, TCDD, and PCB. Lake Ontario saw initial improvement of reproduction with the decline of TCDD and PCB.

Hebert, C. E., Norstrom, R. J., Simon, M., Braune, B. M., Weseloh, D. V., & Macdonald, C. R. (1994). Temporal trends and sources of PCDDs and PCDFs in the Great Lakes: Herring gull egg monitoring, 1981-1991. *Environmental Science & Technology*, *28*(7), 1268-1277.

- PCDD and PCDF levels were found to be the highest in the eggs from Saginaw Bay. There was evidence found for bioaccumulation across species such as trout, walleye, and gull eggs.

Hebert, C. E., Shutt, J. L., Hobson, K. A., & Weseloh, D. C. (1999). Spatial and temporal differences in the diet of Great Lakes herring gulls (*Larus argentatus*): Evidence from stable isotope analysis. *Canadian Journal of Fisheries and Aquatic Sciences*, *56*(2), 323-338.

- Mapping carbon and nitrogen isotopes in gulls showed differences that correlate to terrestrial and aquatic food availability, in which the aquatic had higher nitrogen content than the terrestrial.

Kannan, K., Hilscherova, K., Imagawa, T., Yamashita, N., Williams, L. L., & Giesy, J. P. (2001). Polychlorinated naphthalenes,-biphenyls,-dibenzo-p-dioxins, and-dibenzofurans in double-crested cormorants and herring gulls from Michigan waters of the Great Lakes. *Environmental Science & Technology*, *35*(3), 441-447.

- The ratios of different polychlorinated compounds were compared for cormorants and gulls. Varying ratios suggest that some species may be able to metabolize certain congeners better than other avian species.

Ludwig, J. P., Auman, H. J., Kurita, H., Ludwig, M. E., Campbell, L. M., Giesy, J. P., Tillitt, D.E., Jones, P., Yamashita, N., Tanabe, S., & Tatsukawa, R. (1993). Caspian tern reproduction in the Saginaw Bay ecosystem following a 100-year flood event. *Journal of Great Lakes Research*, *19*(1), 96-108.

- Due to the flooding, sediment carried PCB and TCDD in levels that severely impacted the Caspian tern. The smaller birds were found to be more susceptible to this than the larger of the species which was attributed to higher metabolic rate.

Muter, B. A., Gore, M. L., & Riley, S. J. (2009). From victim to perpetrator: Evolution of risk frames related to human–cormorant conflict in the Great Lakes. *Human Dimensions of Wildlife*, *14*(5), 366-379.

- Assessments of media reports and public opinion were used to determine shifts in views about the human and cormorant relationship.

Nichols, J. W., Larsen, C. P., McDonald, M. E., Niemi, G. J., & Ankley, G. T. (1995). Bioenergetics-based model for accumulation of polychlorinated biphenyls by nestling tree swallows, *Tachycineta bicolor*. *Environmental Science & Technology*, *29*(3), 604-612.

- Model to predict concentrations of residues in the Saginaw River Watershed.

Petrie, S. A., & Wilcox, K. L. (2003). Migration chronology of eastern-population tundra swans. *Canadian Journal of Zoology*, *81*(5), 861-870.

- The use of tracking collars allowed for the determination of times spent in migration areas during certain seasons. The Great Lakes are an important part of the migration area of tundra swans. Tracking like this can provide important information on the area in most need of conservation when relating to migratory birds.

Secord, A. L., McCarty, J. P., Echols, K. R., Meadows, J. C., Gale, R. W., & Tillitt, D. E. (1999). Polychlorinated biphenyls and 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin equivalents in tree swallows from the upper Hudson River, New York State, USA. *Environmental Toxicology and Chemistry*, *18*(11), 2519-2525.

- Concentrations of PCBs in tree swallows were measured and compared to the concentrations found in the Great Lakes. Concentrations in the Hudson River were found to be greater than those in the Saginaw River.

Seston, R. M. (2010). An ecological risk assessment of fish-eating birds exposed to polychlorinated dibenzofurans and dibenzo-p-dioxins within the Tittabawassee River floodplain, MI, USA. *Doctoral dissertation, Michigan State University.*

- The great blue heron and the belted kingfisher were analyzed for polychlorinated toxins. High concentrations were found in nesting sites downstream of industrial hot spots relative to the upstream sites.

Straub, J. N., Gates, R. J., Schultheis, R. D., Yerkes, T., Coluccy, J. M., & Stafford, J. D. (2012). Wetland food resources for spring-migrating ducks in the Upper Mississippi River and Great Lakes Region. *The Journal of Wildlife Management*, *76*(4), 768-777.

- This study suggests that arithmetic means may not correctly estimate food abundance for migrating ducks and suggest that central tendency might be a better option. A model may be needed in this area to fill the gap and more closely determine the distributions of food biomass along areas of waterfowl migration.

Struger, J., Weseloh, D. V., Hallett, D. J., & Mineau, P. (1985). Organochlorine contaminants in herring gull eggs from the Detroit and Niagara Rivers and Saginaw Bay (1978–1982): Contaminant discriminants. *Journal of Great Lakes Research*, *11*(3), 223-230.

- This study determined the levels of 24 organochlorine compounds in rivers and the Saginaw Bay. The areas of Fighting Island through the Detroit River had reports of the worst contamination in herring gull eggs.

Summer, C. L., Bursian, S. J., & Kubiak, T. J. (1996). Effects induced by feeding organochlorine contaminated carp from Saginaw Bay Lake Huron to laying white leghorn hens I: Effects on health of adult hens egg production and fertility. *Journal of Toxicology and Environmental Health*, *49*(4), 389-408.

Summer, C.L., Giesy, J.P., Bursian, S.J., Render, J. A., Jones, P. D., Kubiak, T. J., Verbrugge, D.A., & Aulerich, R. J. (1996). Effects induced by feeding organochlorine contaminated carp from Saginaw Bay Lake Huron to laying white leghorns II embryotoxic and teratogenic effects. *Journal of Toxicology and Environmental Health*, *49*(4).

- Many deformities, similar to the ones observed in the avian species of the Saginaw Bay, were found and characterized. The toxicity was dependent upon dosage. Increases in toxicity resulted in death of embryos however the effects of toxicity and extent of deformities are different across avian species.

Whitt, M. B., Prince, H. H., & Cox Jr, R. R. (1999). Avian use of purple loosestrife dominated habitat relative to other vegetation types in a Lake Huron wetland complex. *The Wilson Bulletin*, 105-114.

- This study determined the density and diversity of avian populations in the invasive loosestrife. It was found that six species of birds were common, such as the red-winged black bird, and that breeding was apparent. Although there was significant high numbers for density, the diversity of species was lower in comparison to other vegetation types.

Wilkins, K. A., Malecki, R. A., Sullivan, P. J., Fuller, J. C., Hindman, L. J., Costanzo, G. R., & Luszcz, D. (2013). Migration routes and bird conservation regions used by eastern population tundra swans *Cygnus columbianus columbianus* in North America. *Wildfowl*, *60*(60), 20-37.

- The use of agriculture and water habitats was greater than that of wetland habitat and should be the focus of conservation specifically in the spring and winter for these birds. The use of wetlands was prompted by changes in food availability and habitat.

i. <u>Avian Botulism</u>

Brand, C. J., Duncan, R. M., Garrow, S. P., Olson, D., & Schumann, L. E. (1983). Waterbird mortality from botulism type E in Lake Michigan: An update. *The Wilson Bulletin*, 269-275.

- Outbreaks of botulism from types C and E were evaluated and were found to be widespread and occurred throughout summer and fall.

Brand, C. J., Schmitt, S. M., Duncan, R. M., & Cooley, T. M. (1988). An outbreak of type E botulism among common loons (*Gavia immer*) in Michigan's upper peninsula. *Journal of Wildlife Diseases*, *24*(3), 471-476.

- The deaths of 592 loons were attributed to the ingestion of dead fish that were infected with botulism.

Byappanahalli, M. N., & Whitman, R. L. (2009). *Clostridium botulinum* type E occurs and grows in the alga *Cladophora glomerata*. *Canadian Journal of Fisheries and Aquatic Sciences*, *66*(6), 879-882.

- Longer incubation times seem to increase the occurrence of type E toxin in the *Cladophora* algal mats sampled. Other types of *Clostridium* were found.

Chun, C. L., Ochsner, U., Byappanahalli, M. N., Whitman, R. L., Tepp, W. H., Lin, G., ... & Sadowsky, M. J. (2013). Association of toxin-producing *Clostridium botulinum* with the macroalga *Cladophora* in the Great Lakes. *Environmental Science & Technology*, *47*(6), 2587-2594.

- Of the areas from which *Cladophora* was collected the type E toxin gene was found in approximately 75% of the samples. Further research was suggested for the determination of specific aspects of the bacteria-algae relationship. Saginaw Bay was not an area that was sampled.

Franson, J. C., & Cliplef, D. J. (1992). Causes of mortality in common loons. In *Proceedings from the 1992 Conference on the Loon and its Ecosystem: Status, Management, and Environmental Concerns* (pp. 2-12).

- Causes of death of over 200 loons were assessed from different states. The highest occurrence of death attributed to avian disease was for those found in Michigan due to botulism outbreaks in Lake Michigan.

Getchell, R. G., & Bowser, P. R. (2006). Ecology of type E botulism within dreissenid mussel beds. *Aquatic Invaders*, *17*(2), 1-8.

Graikoski, J. T., Bowman, E. W., Robohm, R. A., & Koch, R. A. (1970). Distribution of *Clostridium botulinum* in the ecosystem of the Great Lakes. In *Proc. First US-Japan Conference on toxic microorganisms. US Government Printing Office, Washington, DC* (pp. 271-277).

- Determination of outbreaks in the Great Lakes was conducted to facilitate monitoring for the presence of *C. botulinum*.

Hannett, G. E., Stone, W. B., Davis, S. W., & Wroblewski, D. (2011). Biodiversity of *Clostridium botulinum* type E associated with a large outbreak of botulism in wildlife from Lake Erie and Lake Ontario. *Applied and Environmental Microbiology*, *77*(3), 1061-1068.

- The type E toxin was found in large numbers of birds, less in fish, a smaller number in mammals, and was also found in the sediment. Degrees of relatedness were determined and it was found that various distinct strains were involved in the outbreak in Lake Erie.

Lafrancois, B. M., Riley, S. C., Blehert, D. S., & Ballmann, A. E. (2011). Links between type E botulism outbreaks, lake levels, and surface water temperatures in Lake Michigan, 1963–2008. *Journal of Great Lakes Research*, *37*(1), 86-91.

- Correlation was found between low water levels, higher surface water temperature, and increase in *C. botulinum* outbreaks. Predictions of climate change in increasing these factors were mentioned.

Murphy, T., Lawson, A., Nalewajko, C., Murkin, H., Ross, L., Oguma, K., & McIntyre, T. (2000). Algal toxins—Initiators of avian botulism? *Environmental Toxicology*, *15*(5), 558-567.

- The problems associated with carcasses remaining throughout the winter was proposed as a major contributor to outbreaks, along with increases in algae during times of avian molting, which increased risk of infection.

Ortiz, N. E., & Smith, G. R. (1994). Landfill sites, botulism and gulls. *Epidemiology and Infection*, *112*(02), 385-391.

- This study showed landfills as a source of different types of *C. botulinum* and concludes that gulls that scavenge these areas are likely to be a source of distribution for the bacteria.

Pérez-Fuentetaja, A., Clapsadl, M. D., Einhouse, D., Bowser, P. R., Getchell, R. G., & Lee, W. T. (2006). Influence of limnological conditions on *Clostridium botulinum* type E presence in eastern Lake Erie sediments (Great Lakes, USA). *Hydrobiologia*, *563*(1), 189-200.

- Low pH and DO were found with increases in *C. botulinum* in sediment samples. *C. botulinum* was also found in invertebrates.

Smith, G. R. (1976). Botulism in waterfowl. *Wildfowl*, *27*(27), 129-138.

- Overview of the *C. botulinum* bacteria in the context of waterfowl relating characteristics, pathogenesis, and signs of infection.

Wijesinghe, R. U., Oster, R. J., Haack, S. K., Fogarty, L. R., Tucker, T. R., & Riley, S. C. (2015). Spatial, temporal and matrix variability of *Clostridium botulinum* type E toxin gene (bontE) distribution at beaches in the Great Lakes. *Applied and Environmental Microbiology*, AEM-00098.

- Of the samples taken of algae at Bay City State Recreation Area, 83% were found to have the Type E *C. botulinum* and of the sites tested Bay City had the highest concentrations.

Yule, A. M., Barker, I. K., Austin, J. W., & Moccia, R. D. (2006). Toxicity of *Clostridium botulinum* type E neurotoxin to Great Lakes fish: Implications for avian botulism. *Journal of Wildlife Diseases*, *42*(3), 479-493.

- Four fish species were included in the study to determine if they could be a viable transporter of *C. botulinum* to birds of the Great Lakes. This was found to be an avenue of transmittance and yellow perch were found to live the longest after infection of all dose concentrations.

ii. <u>Avian Influenza</u>

Hamer, S. A., Cooley, T. M., & Hamer, G. L. Avian Disease.

- The effects of avian disease are not only detrimental to wildlife populations but H5N1 has risk of infecting humans. It was mentioned that a major gap is in the detection of when diseases emerge, the disease abundance, and the effect it may have on the whole population.

Stumpf, P., Failing, K., Papp, T., Nazir, J., Böhm, R., & Marschang, R. E. (2010). Accumulation of a low pathogenic avian influenza virus in zebra mussels (*Dreissena polymorpha*). *Avian Diseases*, *54*(4), 1183-1190.

- This study proved that zebra mussels that get exposed to H5N1 in water are able to take up the virus and can carry it for at least 14 days in water that does not contain the virus.

d. Mammals

Heaton, S. N., Bursian, S. J., Giesy, J. P., Tillitt, D. E., Render, J. A., Jones, P. D., Verbrugge, D. A., Kubiak, T. J. & Aulerich, R. J. (1995). Dietary exposure of mink to carp from Saginaw Bay, Michigan. 1. Effects on reproduction and survival, and the potential risks to wild mink populations. *Archives of Environmental Contamination and Toxicology*, *28*(3), 334-343.

- PCBs were found to negatively affect the reproduction, health, and offspring of minks exposed to as low as 0.25ppm. The effects of PCBs were greater as the concentrations increased.

Heaton, S. N., Bursian, S. J., Giesy, J. P., Tillitt, D. E., Render, J. A., Jones, P. D., Verbrugge, D. A., Kubiak, T. J. & Aulerich, R. J. (1995). Dietary exposure of mink to carp from Saginaw Bay, Michigan: 2. Hematology and liver pathology. *Archives of Environmental Contamination and Toxicology*, *29*(3), 411-417.

- TEQ and PCB containing diets were given to mink to determine the effects it would have on the liver of females. Lower red blood cell and higher white blood cell counts were found in those exposed to toxic carp, along with behavioral signs of distress. The liver, spleen, and lungs all seemed to be affected based on the greater weight found in comparison to controls.

Kannan, K., Newsted, J., Halbrook, R. S., & Giesy, J. P. (2002). Perfluorooctanesulfonate and related fluorinated hydrocarbons in mink and river otters from the United States. *Environmental Science & Technology*, *36*(12), 2566-2571.

- Mink and river otter livers were tested for concentrations of toxins. Mink livers were found to carry PFOS in every case.

Martin, P. A., Mayne, G. J., Bursian, S., Palace, V., & Kannan, K. (2006). Changes in thyroid and vitamin A status in mink fed polyhalogenated-aromatic-hydrocarbon-contaminated carp from the Saginaw River, Michigan, USA. *Environmental Research*, *101*(1), 53-67.

- Various physiological parameters were considered when determining toxicity directly linked to the ingestion of carp from Saginaw Bay. Some tests showed that the highest percentage toxicity diet had overall effects and some showed it to be no different than the controls.

Restum, E. B. S. J. C., & Bursian, S. J. (1998). Multigenerational study of the effects of consumption of PCB-contaminated carp from Saginaw Bay, Lake Huron, on mink. 3. Estrogen receptor and progesterone receptor concentrations, and potential correlation with dietary PCB consumption. *Journal of Toxicology and Environmental Health Part A*, *54*(5), 403-420.

- Extensive negative effects of mink diets containing PCBs have been proven. Links to hepatic estrogen binding sites and downregulation may play a role; uterine estrogen was not affected as much.

Restum, J. C., Giesy, J. P., Render, J. A., Shipp, E. B., Verbrugge, D. A. & Aulerich, R. J. (1998). Multigenerational study of the effects of consumption of PCB-contaminated carp from Saginaw Bay, Lake Huron, on mink. 1. Effects on mink reproduction, kit growth and survival, and selected biological parameters. *Journal of Toxicology and Environmental Health Part A*, *54*(5), 343-375.

- Duration and time of exposure in parents and offspring to PCB toxins were examined to determine the negative effects in minks.

Shipp, E. B., Giesy, J. P., & Helferich, W. G. (1998). Multigenerational study of the effects of consumption of PCB-contaminated carp from Saginaw Bay, Lake Huron, on mink. 2. Liver PCB concentration and induction of hepatic cytochrome P-450 activity as a potential biomarker for PCB exposure. *Journal of Toxicology and Environmental Health Part A*, *54*(5), 377-401.

- PCB exposure may be able to be determined by use of biomarkers using liver enzyme activity as related to cytochrome P-450 induction.

Tillitt, D. E., Gale, R. W., Meadows, J. C., Zajicek, J. L., Peterman, P. H., Heaton, S. N., ... & Aulerich, R. J. (1995). Dietary exposure of mink to carp from Saginaw Bay. 3. Characterization of dietary exposure to planar halogenated hydrocarbons, dioxin equivalents, and biomagnification. *Environmental Science & Technology*, *30*(1), 283-291.

- PHH and TCDD showed additive effects on the minks as found by bioassay. Mink are extremely sensitive to reproductive toxicity from these compounds.

Ecological Stressors

IV. Environmental Degradation

a. Soil and Sediment

i. Soil Movement

Cardenas, M., Gailani, J., Zeigler, C. K., & Lick, W. (1995). Sediment transport in the lower Saginaw River. *Marine and Freshwater Research*, *46*(1), 337-347.

- Model incorporating time and transport of sediments was used to determine the sedimentation and movement and the resulting river bed bathymetry that has changed as a result. This study also showed uses of the model in long term prediction of changes.

Hawley, N., Redder, T., Beletsky, R., Verhamme, E., Beletsky, D., & DePinto, J. V. (2014). Sediment resuspension in Saginaw Bay. *Journal of Great Lakes Research*, *40*, 18-27.

- Transportation models were developed to address hydrodynamics in Saginaw Bay. It was found that seasonality affects resuspension events, mostly attributed to surface waves.

He, C. (1999). Incorporating soil associations into linear programming models for development of irrigation scenarios. *Geographical Analysis*, *31*(3), 236-248.

- This study showed soil associations and models for irrigation in the Saginaw Bay.

He, C., & Zhang, L. Estimating soil and streambank erosion in the Great Lakes Watersheds. *Recent Advances in Image, Audio, and Signal Processing*, 28-34.

- A simulation model was used in conjunction with GIS and other tools to attempt the estimation of erosion. AGNPS model was used and it was found that the Cass River Watershed contributed greatly to the sedimentation in the Saginaw Bay and River.

Karlen, D. L., Andrews, S. S., & Doran, J. W. (2001). Soil quality: Current concepts and applications. *Advances in Agronomy*, *74*, 1-40.

- The focus of this paper is to present the uses of soil quality parameters as a tool for the development of research and to influence land uses, particularly to promote sustainability in agriculture.

Munday, J. C., & Alföldi, T. T. (1979). Landsat test of diffuse reflectance models for aquatic suspended solids measurement. *Remote Sensing of Environment*, *8*(2), 169-183.

- LANDSAT – reflectance data was used in mathematical models to relate it to suspended solids in water.

Ouyang, D., & Bartholic, J. (1997). Predicting sediment delivery ratio in Saginaw Bay watershed. *Proceedings of the 22nd National Association of Environmental Professionals Conference*, 659-671.

Phillips, N. (1993). Saginaw Bay watershed sediment delivery and erosion potential GIS study. *Report by Atlantic Research Corporation and US Environmental Protection Agency, Region, 5*.

Stone, A. G., Riedel, M. S., Dahl, T., & Selegean, J. (2010). Application and validation of a GIS-based stream bank stability tool for the Great Lakes region. *Journal of Soil and Water Conservation*, *65*(4), 92A-98A.

- In the Sebewaing Watershed, the Channel Sustainability Tool was employed to help address agricultural drainage issues and explore BMPs.

ii. <u>Sediment Pollution</u>

Horii, Y., Ohura, T., Yamashita, N., & Kannan, K. (2009). Chlorinated polycyclic aromatic hydrocarbons in sediments from industrial areas in Japan and the United States. *Archives of Environmental Contamination and Toxicology*, *57*(4), 651-660.

- Concentration and patterns of polycyclic aromatic hydrocarbons were analyzed in sediments of different parts of the world including Saginaw Bay.

Marvin, C., Painter, S., & Rossmann, R. (2004). Spatial and temporal patterns in mercury contamination in sediments of the Laurentian Great Lakes. *Environmental Research*, *95*(3), 351-362.

- Sediment analysis showed Lake Huron to be the Great Lake least contaminated with mercury and suggest that the source may be natural for this lake.

Meyers, P. A. (2006). An overview of sediment organic matter records of human eutrophication in the Laurentian Great Lakes region. *The Interactions Between Sediments and Water*, 89-99.

- Retrospective analysis on human disturbances and the changes that resulted in the Great Lakes were discussed.

Yun, S. H., Addink, R., McCabe, J. M., Ostaszewski, A., Mackenzie-Taylor, D., Taylor, A. B., & Kannan, K. (2008). Polybrominated diphenyl ethers and polybrominated biphenyls in sediment and floodplain soils of the Saginaw River watershed, Michigan, USA. *Archives of Environmental Contamination and Toxicology*, *55*(1), 1-10.

- Polybrominated biphenyls were analyzed in sediments from different areas around the Tittabawassee and Saginaw Rivers as well as the Saginaw Bay. The highest concentrations were found at the mouth of the Saginaw River.

Yun, S. H., & Kannan, K. (2011). Distribution of mono-through hexa-chlorobenzenes in floodplain soils and sediments of the Tittabawassee and Saginaw Rivers, Michigan. *Environmental Science and Pollution Research*, *18*(6), 897-907.

- A spatial trend of concentration of chlorobenzenes was found.

1. Dioxins and Furans in Sediment

Czuczwa, J. M., & Hites, R. A. (1984). Environmental fate of combustion-generated polychlorinated dioxins and furans. *Environmental Science & Technology*, *18*(6), 444-450.

- The use of dioxins and furans has contributed to the sediment concentration of these toxins in sediments of the Saginaw Bay. The release of these toxins from burning was suggested as a major source of the contamination.

Dow Chemical Company (2005). Tittabawassee River sediment dioxin/furan concentration vertical variability. *trwnews.net*.

- Extensive research in sediment was conducted for the Dow Chemical Company. Higher concentrations of toxins were found in surface sediments rather than deeper in the sediment on average.

Hilscherova, K., Kannan, K., Nakata, H., Hanari, N., Yamashita, N., Bradley, P. W., Mccabe, J. M., Taylor, A. B. & Giesy, J. P. (2003). Polychlorinated dibenzo-p-dioxin and dibenzofuran concentration profiles in sediments and flood-plain soils of the Tittabawassee River, Michigan. *Environmental Science & Technology*, *37*(3), 468-474.

- Total organic carbon did not correlate with sediment toxin concentration, however downstream concentrations were higher.

Homer, M. P., & Bissell, F. K. (1996). Trends of PCBs, PCDDs and PCDFs in federal navigation channel sediments, Saginaw River, Michigan. *Water Quality*.

- Past and present contamination concentrations were analyzed for the Saginaw River. Trends in degraded contaminates were observed.

Kannan, K., Yun, S. H., Ostaszewski, A., McCabe, J. M., Mackenzie-Taylor, D., & Taylor, A. B. (2008). Dioxin-like toxicity in the Saginaw River watershed: Polychlorinated dibenzo-p-dioxins, dibenzofurans, and biphenyls in sediments and floodplain soils from the Saginaw and Shiawassee Rivers and Saginaw Bay, Michigan, USA. *Archives of Environmental Contamination and Toxicology*, *54*(1), 9-19.

- Polychlorinated dioxins and furans were found in the highest concentration in the Saginaw River and Bay in comparison to other areas of the watershed. The data suggested a source of PCDF's in the watershed rather than the river.

Robbins, J. A. (1986). Sediments of Saginaw Bay, Lake Huron: Elemental composition and accumulation rates (No. 102). Environmental Research Laboratory--Duluth Office of Research and Development, *US Environmental Protection Agency*.

Shen, L., Gewurtz, S. B., Reiner, E. J., MacPherson, K. A., Kolic, T. M., Khurana, V., Helm, P. A., Howell, E. T., Burniston, D. A., Brindle, I. D. & Marvin, C. H. (2009). Occurrence and sources of polychlorinated dibenzo-*p*-dioxins, dibenzofurans and dioxin-like polychlorinated biphenyls in surficial sediments of Lakes Superior and Huron. *Environmental Pollution*, *157*(4), 1210-1218.

- The chemical treating of products in industry and atmospheric deposition were the main causes discussed for the sediment contamination found.

Ullman, W. J., & Aller, R. C. (1989). Nutrient release rates from the sediments of Saginaw Bay, Lake Huron. *Hydrobiologia*, *171*(2), 127-140.

- It was determined that the data shows steady state fluxes and kinetic rates which were calculated and silica fluxes were extrapolated.

Wood, L. E. (1964). Bottom sediments of Saginaw Bay, Michigan. *Journal of Sedimentary Research*, *34*(1).

- General correlations were found for spatially distributed particles of sediment. Diameters and other characteristics were measured and related to waves and water movement.

iii. <u>Muck</u>

Rose, J. B., Ives, R. L., & Bellows, L. (2007). Microbiological quality of Saginaw Bay State Park. *Department of Fisheries and Wildlife; Michigan State University.*

- The microorganisms in the muck of the Saginaw Bay were tested for identification and for the determination of possible fecal contamination by identifying species such as *E. coli*. The results showed fecal contamination.

Singh, S., & Rose, J. B. (2007). Further investigation of water quality and muck at Saginaw Bay Parks and Beaches. *Department of Fisheries and Wildlife; Michigan State University*.

- Several bacterial species were identified in the muck of the Saginaw Bay. Both animal and human sources of fecal contamination were found.

b. Water Contaminants

Beeton, A. M., Smith, S. H., & Hooper, F. H. (1967). Physical Limnology of Saginaw Bay, Lake Huron (No. 12). Great Lakes Fishery Commission.

- Analysis of the flow and circulation of Lake Huron showed how the mixing affects the chemical and water temperature parameters in the Bay and the variability that this produces when measuring contaminants that come from the Saginaw River as they decrease to the outer bay.

Croley, T.E., II (2002), 'Large Basin Runoff Model,' In *Mathematical Models of Large Watershed Hydrology* (V. Singh, D. Frevert, and S. Meyer, Eds.), Water Resources Publications, Littleton, Colorado, 717-770.

- DLBRM Distributed Large Basin Runoff Model- NOAA GLERL.

Croley, T. E., & He, C. (2005). Great Lakes spatially distributed watershed model of water and materials runoff. In *International Conference on Poyang Lake Wetland Ecological Environment*.

- Watershed model for materials runoff in the Great Lakes and Saginaw Bay.

Dolan, D. M., & Bierman, V. J. (1982). Mass balance modeling of heavy metals in Saginaw Bay, Lake Huron. *Journal of Great Lakes Research*, *8*(4), 676-694.

- Model used for concentrations of heavy metals in suspended solids and sediments in the Saginaw Bay.

Douglas-Mankin, K. R., Srinivasan, R., & Arnold, J. G. (2010). Soil and water assessment tool (SWAT) model: Current developments and applications. *Trans. ASABE*, *53*(5), 1423-1431.

- SWAT- Soil and Water Assessment Tool- USDA Agricultural Research Service (ARS) continuous time model, Total Maximum Daily Load (TMDL)

Engel, B. (2003). Long-term hydrologic impacts assessment and non-point source pollutant model. *Version-2.3 Manual, 7*.

He, C., & DeMarchi, C. (2010). Modeling spatial distributions of point and nonpoint source pollution loadings in the Great Lakes watersheds. *International Journal of Environmental Science and Engineering*, *2*(1), 24-30.

- Estimation of loading potential of non-point sources in the Great Lake Watersheds.

He, C., Riggs, J. F., & Kang, Y. T. (1993). Integration of geographic information systems and a computer model to evaluate impacts of agricultural runoff on water quality1. 891-900.

- AGNPS- Agricultural Non-Point Source Pollution Model; GRASS- Geographic Resource Analysis Support System; GRASS WATERWORKS tool box for hydrologic modeling; Incorporation of different models for land use, amounts of erosion, nitrogen, phosphorus, volume of runoff, and sediment yields.

Kao, Y. C., Adlerstein, S., & Rutherford, E. (2014). The relative impacts of nutrient loads and invasive species on a Great Lakes food web: An ecopath with ecosim analysis. *Journal of Great Lakes Research*, *40*, 35-52.

- Ecopath (for biomass flows among groups using mass balance modeling) and Ecosim (considered migration and nutrient concentrations and loads with dynamic modeling) models for modeling invasive species and their effects for Saginaw Bay.

Lahlou, M., Shoemaker, L., Choudhury, S., Elmer, R., & Hu, A. (1998). *Better assessment science integrating point and nonpoint sources (BASINS), version 2.0. User's Manual* (No. PB--99-121295/XAB). Tetra Tech, Inc., Fairfax, VA (United States); EarthInfo, Inc., Boulder, CO (United States); Environmental Protection Agency, Standards and Applied Science Div., Washington, DC (United States).

- BASINS- Better Assessment Science Integrating Point and Non-point Sources – EPA.

Lee, K. W., Filkins, J. C., Hartwell, K. W., Rygwelski, K. R., & Townsend, J. M. (1977). *Survey of chemical factors in Saginaw Bay (Lake Huron)*. Environmental Research Laboratory, Office of Research and Development, US Environmental Protection Agency.

- The development of simulation models for pollution, such as nitrogen and phosphorus, were used to acquire water quality baseline measurements for Saginaw Bay.

Moll, R. A., Jude, D., Rossmann, R., Kantak, G. V., Barres, J., DeBoe, S., Giesy, J. & Tuchman, M. (1995). Movement and loadings of inorganic contaminants through the lower Saginaw River. *Journal of Great Lakes Research*, *21*(1), 17-34.

- The concentrations of four heavy metals were found to vary greatly due to river discharge and seasonal changes. The source of contaminants was found to be in the lower 8 km of the river.

Robertson, D. M., & Saad, D. A. (2011). Nutrient inputs to the Laurentian Great Lakes by source and watershed estimated using SPARROW watershed models1. *JAWRA Journal of the American Water Resources Association*, *47*(5), 1011-1033.

- SPAtially Referenced Regressions On Watershed attributes (SPARROW) – estimation of phosphorus and nitrogen loads.

SAGEM2- Saginaw Bay Aquatic Ecosystem Model- Limno Tech

Scavia, D., Canale, R. P., Powers, W. F., & Moody, J. L. (1981). Variance estimates for a dynamic eutrophication model of Saginaw Bay, Lake Huron. *Water Resources Research*, *17*(4), 1115-1124.

- Models were used to explore variances of different parameters.

Verbrugge, D. A., Giesy, J. P., Mora, M. A., Williams, L. L., Rossmann, R., Moll, R. A., & Tuchman, M. (1995). Concentrations of dissolved and particulate polychlorinated biphenyls in water from the Saginaw River, Michigan. *Journal of Great Lakes Research*, *21*(2), 219-233.

- The total and soluble PCB concentrations in the river were analyzed and helped to determine the concentration and loading at different sites on the river.

Wool, T. A., Ambrose, R. B., Martin, J. L., Comer, E. A., & Tech, T. (2001). Water Quality Analysis Simulation Program (WASP). *User's Manual, Version*, *6*.

- WASP from the EPA- Water quality Analysis Simulation Program – Takes into account multiple types of pollution.

i. **Phosphorus**

Alexander JR, G. R. (2009). The rationale for a ban on detergent phosphate in the Great Lakes Basin. *Phosphorus in the Environment: Its Chemistry and Biochemistry*, *919*, 269.

- This ban aids to reduce the amount of phosphorus that needs to be treated and removed therefore lowering the amounts of chemical reagents needing to be used and making treatment more effective by lessening the starting amount.

Ballard, M. M., Jackson, M., Leav, J., & Ethen, S. (2010). Understanding and quantification of phosphorus loading into the Laurentian Great Lakes. M*ichigan Technological University.*

- The necessity of needing to predict phosphorus loads in times where sampling doesn't occur prompted the use of different models for this prediction.

Bierman, V. J., Dolan, D. M., Kasprzyk, R., & Clark, J. L. (1984). Retrospective analysis of the response of Saginaw Bay, Lake Huron, to reductions in phosphorus loadings. *Environmental Science & Technology*, *18*(1), 23-31.

- Greater than 50% decreases in phosphorus loadings to the Saginaw Bay were observed in 1980 in comparison to 1974. Other water quality parameters including chlorophyll and Secchi depth were measured.

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

- Bayesian network for phosphorus and chlorophyll a in the Saginaw Bay.

Cha, Y., Stow, C. A., Reckhow, K. H., DeMarchi, C., & Johengen, T. H. (2010). Phosphorus load estimation in the Saginaw River, MI using a Bayesian hierarchical/multilevel model. *Water Research*, *44*(10), 3270-3282.

- Estimation of phosphorus load using a Bayesian model that allows for the reduction of uncertainty that accompanies small sample sizes.

Chapra, S. C. (1979). Applying phosphorus loading models to embayments. *Limnology and Oceanography*, *24*(1), 163-168.

- Modification of models including flow and diffusion of phosphorus in the Saginaw Bay.

Chapra, S. C., & Robertson, A. (1977). Great Lakes eutrophication: The effect of point source control of total phosphorus. *Science*, *196*(4297), 1448-1450.

- Mathematical phosphorus models determined the amount of phosphorus reduction that could induce significant benefits in the reduction of eutrophication.

Ellis, R., Davis, J. F., & Thurlow, D. L. (1964). Zinc availability in calcareous Michigan soils as influenced by phosphorus level and temperature. *Soil Science Society of America Journal*, *28*(1), 83-86.

- Experiments in both the field and in a greenhouse showed the correlation between zinc and phosphorus as negative, found through different variations of applied zinc/phosphorus to corn plants and soil.

Hecky, R. E., Smith, R. E., Barton, D. R., Guildford, S. J., Taylor, W. D., Charlton, M. N., & Howell, T. (2004). The nearshore phosphorus shunt: A consequence of ecosystem engineering by dreissenids in the Laurentian Great Lakes. *Canadian Journal of Fisheries and Aquatic Sciences*, *61*(7), 1285-1293.

- A conceptual model developed for the changes that *Dreissena* have made in the nutrient and energy flow to address the nearshore phosphorus shunt. Mentions the necessity of heavy phosphorus management in areas were *Dreissena* have become established.

Kashian, D. R., Oates, R. H., & Johengen, T. H. (2010, August). COS 45-5: Biotic and physical influences on internal phosphorus loading in a Great Lakes coastal system. *The 95th ESA Annual Meeting*.

- Anoxic water conditions correlated with an increase in phosphorus release into the water. This study called into question the temporal variability of zebra mussel deposits and their release of phosphorus due to there being no evidence of release found from them in this study period.

Nalepa, T. F., Fanslow, D. L., Lansing, M. B., & Lang, G. A. (2003). Trends in the benthic macroinvertebrate community of Saginaw Bay, Lake Huron, 1987 to 1996: Responses to phosphorus abatement and the zebra mussel, *Dreissena polymorpha*. *Journal of Great Lakes Research*, *29*(1), 14-33.

- The shifts that have occurred after the invasive zebra mussel have caused a greater split in the environments of the nearshore and outer bay regions. The inner and outer bay saw changes in macroinvertebrates.

Schelske, C. L., Stoermer, E. F., Fahnenstiel, G. L., & Haibach, M. (1986). Phosphorus enrichment, silica utilization, and biogeochemical silica depletion in the Great Lakes. *Canadian Journal of Fisheries and Aquatic Sciences*, *43*(2), 407-415.

- This study proposed that Si depletion can be attributed to the increase in its uptake by diatoms which are affected by levels of phosphorus in the Great Lakes. A model was proposed for biogeochemical depletion.

Stow, C. A., Dyble, J., Kashian, D. R., Johengen, T. H., Winslow, K. P., Peacor, S. D., ... & Miller, D. (2014). Phosphorus targets and eutrophication objectives in Saginaw Bay: A 35-year assessment. *Journal of Great Lakes Research*, *40*, 4-10.

- Phosphorus input into the Saginaw Bay is still too high when compared to the standards proposed for the reduction of eutrophication. This indicates a need for increased effort in reduction and water quality management.

Tao, W., DeMarchi, C., He, C., Johengen, T. H., & Stow, C. (2010). Estimating phosphorous load from a large watershed in the Great Lakes Basin. In *Challenges in Environmental Science and Computer Engineering (CESCE), 2010 International Conference on* (Vol. 1, pp. 427-430). IEEE.

- Estimating phosphorous load for the Saginaw Bay was the focus.

ii. <u>Nitrogen</u>

Conroy, J. D., Edwards, W. J., Pontius, R. A., Kane, D. D., Zhang, H., Shea, J. F., ... & Culver, D. A. (2005). Soluble nitrogen and phosphorus excretion of exotic freshwater mussels (*Dreissena* spp.): Potential impacts for nutrient re-mineralization in western Lake Erie. *Freshwater Biology*, *50*(7), 1146-1162.

- A comparison of the excretion concentration of nutrients from both zebra and quagga mussels were tested to determine if there were differences present that could account for the changes in community distribution and the increase in harmful algal blooms. Quagga mussels were found to have lower rates of excretion in comparison. The increases in nitrogen and phosphorus cycling from mussels contribute to the overgrowth of algae.

DePinto, J. V., Bierman, V. J., & Verhoff, F. H. (1976). Seasonal phytoplankton succession as a function of species competition for phosphorus and nitrogen. In *Modeling Biochemical Processes in Aquatic Ecosystems* (pp. 141-170). Ann Arbor Science Ann Arbor, Mich.

Gardner, W. S., Cavaletto, J. F., Johengen, T. H., Johnson, J. R., Heath, R. T., & Cotner, J. B. (1995). Effects of the zebra mussel, *Dreissena polymorpha*, on community nitrogen dynamics in Saginaw Bay, Lake Huron. *Journal of Great Lakes Research*, *21*(4), 529-544.

- A possible positive nitrogen regeneration effect was suggested based on the rates of ammonium regeneration which were increased with the presence of zebra mussels.

Gardner, W. S., Yang, L., Cotner, J. B., Johengen, T. H., & Lavrentyev, P. J. (2001). Nitrogen dynamics in sandy freshwater sediments (Saginaw Bay, Lake Huron). *Journal of Great Lakes Research*, *27*(1), 84-97.

- At two sites on the Saginaw Bay, water-sediment ammonium fluxes were measured. The zebra mussels play a role in nitrogen generation due to excretion.

Lavrentyev, P. J., Gardner, W. S., & Yang, L. (2000). Effects of the zebra mussel on nitrogen dynamics and the microbial community at the sediment-water interface. *Aquatic Microbial Ecology, 21*, 187-194.

- Nitrogen cycling at the sediment-water interface was the basis for the study and it was determined that the excretion of ammonia by the zebra mussels heavily influence the microbial community by increasing nitrogen.

Schelske, C. L. (1975). Silica and nitrate depletion as related to rate of eutrophication in Lakes Michigan, Huron, and Superior. In Coupling of land and water systems (pp. 277-298). Springer Berlin Heidelberg.

- A trophic state model was used to determine changes in nutrient levels in some of the Great Lakes. The rates of eutrophication were applied to nitrate content.

iii. Carbonate

Effler, S. W. (1984). Carbonate equilibria and the distribution of inorganic carbon in Saginaw Bay. *Journal of Great Lakes Research*, *10*(1), 3-14.

- Conditions of carbon dioxide and calcite equilibrium can be used as indicators of biological integrity due to biochemical reactions. This method was used for 11 sites in Saginaw Bay. Conditions varied seasonally. Photosynthetic activity was of importance nearshore, where in the outer bay temperature played an important role.

Heath, C. R., Callow, M. E., & Leadbeater, B. S. C. (1992). Deposition of calcium carbonate within algal biofilms on antifouling paints in hard waters. In *Biofilms—Science and Technology* (pp. 551-556). Springer Netherlands.

- The microenvironment of the water plays an important role in the cycling of carbon and the deposition of calcium carbonate by photosynthetic action, resulting removal of CO_2 by algae on certain anti-algae paint on boats.

Kemp, A. L. W. (1971). Organic carbon and nitrogen in the surface sediments of Lakes Ontario, Erie and Huron. *Journal of Sedimentary Research*, *41*(2).

- The clay content of the sediment was proportional to the amount of carbon found with Lake Huron and Ontario, which had higher amounts than Lake Erie. Higher concentrations of both carbon and nitrogen were found in the surface of sediments. Carbon and nitrogen were found to be proportional.

iv. E. coli

Bauer, L., & Alm, E. (2012). Escherichia coli toxin and attachment genes in sand at Great Lakes recreational beaches. *Journal of Great Lakes Research*, *38*(1), 129-133.

- Virulence genes associated with the pathogenic strains of *E. coli* were not common in the beach sand, however attachment genes were common.

Englebert, E. T., McDermott, C., & Kleinheinz, G. T. (2008). Effects of the nuisance algae, *Cladophora*, on *Escherichia coli* at recreational beaches in Wisconsin. *Science of the Total Environment*, *404*(1), 10-17.

- The correlation of *E. coli* and *Cladophora* was examined. Although it was stated that *E. coli* concentration was greater in dense areas of algae when compared to the surrounding water, there were problems with statistical significance in determining spatial distribution of *E. coli* from the algae.

Englebert, E. T., McDermott, C., & Kleinheinz, G. T. (2008). Impact of the alga *Cladophora* on the survival of *E. coli*, *Salmonella*, and *Shigella* in laboratory microcosm. *Journal of Great Lakes Research*, *34*(2), 377-382.

- In relation to the other fecal pathogens studied, *E. coli* was able to last 45 days with *Cladophora* much longer than either of the other pathogens studied.

O'Keefe, J., Rieger, K., & Rediske, J. D. (2010). Assessment of *E. coli* and Microcystins in *Cladophora* mats in the nearshore waters of Grand Traverse Bay, Little Traverse Bay, and Saginaw Bay.

- Correlation of *E. coli* concentrations between water and those of *Cladophora* was not found. Detached *Cladophora* was examined for *E. coli*. The highest concentrations were found for the Saginaw Bay and this was attributed to the higher phosphorus concentrations found there.

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

- The highest concentrations of *E. coli* were found in shallow waters, sediment, and algal mats. The species specific testing showed predominance of contamination by human fecal source. Areas of high concentration are sensitive to disturbances such as movement from various sources.

v. **Flow**

Allan, D., & Hinz, L. (2004). An assessment of flows for rivers of the Great Lakes Basin. *School of Natural Resources & Environment: The University of Michigan*, *48109*, 1115.

- An attempt to characterize flow regimes as well as look at the historical flow and what may have caused the changes. This study also included a GIS attachment for developing hydrographs along with other tools. Flow Assessment by U of M used ESRI ArcView 3.X GIS modified to construct hydrographs, retrieve information about dams, and access contact information for the Great Lakes Basin.

Danek, L. J., & Saylor, J. H. (1977). Measurements of the summer currents in Saginaw Bay, Michigan. *Journal of Great Lakes Research*, *3*(1), 65-71.

- The currents measured in the inner bay agreed with the model used in contrast with the outer bay, in which the models did not accurately represent data. The water exchange was dependent upon the direction of the wind in regards to the Bay.

Hoaglund, J. R., Kolak, J. J., Long, D. T., & Larson, G. J. (2004). Analysis of modern and Pleistocene hydrologic exchange between Saginaw Bay (Lake Huron) and the Saginaw Lowlands area. *Geological Society of America Bulletin*, *116*(1-2), 3-15.

- Groundwater flow and hydraulic loading simulation models were used to analyze groundwater exchange for the Saginaw Bay.

Johnson, L. B., Richards, C., Host, G. E., & Arthur, J. W. (1997). Landscape influences on water chemistry in mid-western stream ecosystems. *Freshwater Biology*, *37*, 193-208.

- This study showed the variance in water quality associated with seasonality and land use. This study stressed the importance of databases that show spatial distribution of water quality which can be applied to a region.

Ris, R. C., Holthuijsen, L. H., & Booij, N. (1994). A spectral model for waves in the near shore zone. *Coastal Engineering Proceedings*, *1*(24).

- SWAN developed for a wave model for the Saginaw Bay.

Scharffenberg, W. (2001). *Hydrologic Modeling System* (Vol. 2). CA: Davis. HEC—HMS, edition.

- The Hydrologic Modeling System (HEC-HMS) simulates the hydrologic processes by both event and continuous simulations. Additional tools such as

depth, flow, sedimentation, erosion and nutrient water quality are available to estimate such parameters for watershed systems.

Anthropogenic Conditions

V. Anthropogenic Stress

a. Human Disturbances

Albert, D. A. (2005). The impacts of various types of vegetation removal on Great Lakes coastal wetlands of Saginaw Bay and Grand Traverse Bay. *Michigan Natural Features Inventory*.

- Variance in vegetation is found in different areas. Different types of removal strategies can reduce the diversity of plant life, cause root degradation, and erosion.

Brandon, D. L., Lee, C. R., Simmers, J. W., Tatem, H. E., & Skogerboe, J. G. (1991). *Information Summary, Area of Concern: Saginaw River and Saginaw Bay* (No. WES/MP/EL-91-7). Army Engineer Waterways Experiment Station Vicksburg MS Environmental Lab.

- Contamination mobility was researched in areas of concern to obtain information for a Remedial Action Plan.

Brown, D. G., Pijanowski, B. C., & Duh, J. D. (2000). Modeling the relationships between land use and land cover on private lands in the Upper Midwest, USA. *Journal of Environmental Management*, *59*(4), 247-263.

- Regression and Markov Models were used for the prediction of the changes in forest cover due to socioeconomic changes in land use.

Einheuser, M. D., Nejadhashemi, A. P., Wang, L., Sowa, S. P., & Woznicki, S. A. (2013). Linking biological integrity and watershed models to assess the impacts of historical land use and climate changes on stream health. *Environmental Management*, *51*(6), 1147-1163.

- This study used a watershed model for land use and climate change in the Saginaw Bay.

He, C. (1999). Assessing regional crop irrigation requirements and streamflow availability for irrigation development in Saginaw Bay, Michigan. *Geographical Analysis*, *31*(2), 169-186.

- Simulation model for irrigation purposes with concern for water quality degradation were developed.

Holeck, K. T., Mills, E. L., MacIsaac, H. J., Dochoda, M. R., Colautti, R. I., & Ricciardi, A. (2004). Bridging troubled waters: Biological invasions, transoceanic shipping, and the Laurentian Great Lakes. *BioScience*, *54*(10), 919-929.

- Ship ballast water methods of contamination have contributed greatly to invasive species. The presence of interchanges such as canals are projected to continue to introduce more non-native species.

Ikehata, K., Liu, Y., & Sun, R. (2009). Health effects associated with wastewater treatment, reuse, and disposal. *Water Environment Research, 81*(10), 2126-2146.

- Many issues in regards to waste water were addressed such as occupational risks, pharmaceuticals and other toxins, viruses, diseases, and more.

Johnston, C. A., Ghioca, D. M., Tulbure, M., Bedford, B. L., Bourdaghs, M., Frieswyk, C. B., ... & Zedler, J. B. (2008). Partitioning vegetation response to anthropogenic stress to develop multi-taxa wetland indicators. *Ecological Applications*, *18*(4), 983-1001.

- Models were developed for the indication of wetland condition based on seven taxa and four taxa models of emergent plants in the Great Lakes.

Johnston, C. A., Zedler, J. B., Tulbure, M. G., Frieswyk, C. B., Bedford, B. L., & Vaccaro, L. (2009). A unifying approach for evaluating the condition of wetland plant communities and identifying related stressors. *Ecological Applications, 19*(7), 1739-1757.

- An attempt to determine wetland health by taking into account human stressors, water depth, biological conditions, and geography was made. They employed CART models for analysis.

Mills, E. L., Leach, J. H., Carlton, J. T., & Secor, C. L. (1993). Exotic species in the Great Lakes: A history of biotic crises and anthropogenic introductions. *Journal of Great Lakes Research, 19*(1), 1-54.

- Determination of invasive species entry was focused on in the retrospective review on non-native species.

Morrice, J. A., Danz, N. P., Regal, R. R., Kelly, J. R., Niemi, G. J., Reavie, E. D., Hollenhorst, T., Axler, R. P., Trebitz, A. S., Cotter, A. M. & Peterson, G. S. (2008). Human influences on water quality in Great Lakes coastal wetlands. *Environmental Management, 41*(3), 347-357.

- Human stressors and their relationships to water quality and geology were analyzed.

Niemi, G. J., Brady, V. J., Brown, T. N., Ciborowski, J. J., Danz, N. P., Ghioca, D. M., Hankowski, J. M., Hollenhorst, T. P., Howe, R. W., Johnson, L. B., Johnston, C.A. & Reavie, E. D. (2009). Development of ecological indicators for the US Great Lakes coastal region–A summary of applications in Lake Huron. *Aquatic Ecosystem Health & Management*, *12*(1), 77-89.

- Extensive research was done on 88 sites of Lake Huron to determine health conditions as well as to suggest sources of stress and human disturbances based on gradients and four different health indicators.

Pijanowski, B. C., Gage, S. H., Long, D. E., & Cooper, W. E. (2000). A land transformation model for the Saginaw Bay Watershed, Sanderson J., Harris L. *Landscape Ecology: A Top Down Approach*, *246*.

- Land transformation model for the Saginaw Bay Watershed.

Smith, S. D., McIntyre, P. B., Halpern, B. S., Cooke, R. M., Marino, A. L., Boyer, G. L., ... & Allan, J. D. (2015). Rating impacts in a multi-stressor world: A quantitative assessment of 50 stressors affecting the Great Lakes.

- An online survey attempted to attach priority to certain environmental stressors. Less priority was given to pollution and more priority was given to climate change and invasive species threats.

Vannier, R. G. (2014). Understanding geochemical recovery in anthropogenically disturbed landscapes. *Doctoral dissertation, Michigan State University.*

- DDT and PCB were the main chemicals analyzed. The effects of land use, seasonality, and surface water components were incorporated into the study of Michigan Lakes.

b. Remediation/ Conservation Efforts

Allen, A. W. (2005). The conservation reserve enhancement program. *USGS Staff--Published Research*, 191.

- Conservation program with a focus on agriculture. Monitoring programs are in place to determine the success of the program.

Bacon, E., Rogers, J., Kieser, M., McElwaine, A., & Peluso, C. (2002). Incentives and tools for TMDL implementation and achievement of voluntary goals in two Michigan watersheds. *Proceedings of the Water Environment Federation*, *13*, 836-845.

- The dynamics of tradable credits for reduction of nutrient loading were explored. Models gave insight into the estimation of nutrient reduction upon implementation.

Bartholic, J. F., Kang, Y. T., Phillips, N., & He, C. (1995). Saginaw Bay integrated watershed prioritization and management system. *Water Resources Update (USA)*.

- Discussed are the needs for prioritization of watersheds and areas in need of BMP's for the best action for conservation efforts.

Bails, J., & Federation, W. (2005). Prescription for Great Lakes ecosystem protection and restoration.

- A look at the history of the Great Lakes ecosystem breakdowns and the focus of how to manage this before the damage becomes irreversible due continuing stressors on the self-regulating systems of the Great Lakes.

Batie, S. S., Schulz, M. A., & Schweikhardt, D. B. (1998). The environmental quality incentives program: Locally managing natural resources. *Public Policies & Public Choices: Issues for Michigan. Michigan State University Staff Paper 98-03.*

Butterworth, E. M., & Hough, R. (1998). Rehabilitation of the North American Great Lakes watershed: Past and future. *John Wiley, London*.

Campbell, L. M., Allan, J. D., McIntyre, P. B., Smith, S. D., Halpern, B. S., Boyer, G. L., ... & Steinman, A. D. (2013). Joint analysis of stressors and ecosystem services to enhance restoration effectiveness.

- This study considers the compounding effects of multiple stressors and the importance of looking at all aspects that affect the health of the waters to focus restoration efforts.

Caudill, S. B., Groothuis, P. A., & Whitehead, J. C. (2011). The development and estimation of a latent choice multinomial logit model with application to contingent valuation. *American Journal of Agricultural Economics*.

- The study sought out the determination of bias in models with a focus on data from the Saginaw Bay.

Detenbeck, N. E., Galatowitsch, S. M., Atkinson, J., & Ball, H. (1999). Evaluating perturbations and developing restoration strategies for inland wetlands in the Great Lakes Basin. *Wetlands, 19*(4), 789-820.

- Distinctions between human disturbances and stressors are made and suggestions are given for habitat improvement.

Einheuser, M. D., Nejadhashemi, A. P., Sowa, S. P., Wang, L., Hamaamin, Y. A., & Woznicki, S. A. (2012). Modeling the effects of conservation practices on stream health. *Science of The Total Environment*, *435*, 380-391.

- ANFIS and SWAT were used along with macroinvertebrate measurements to determine the impact of best management practices on stream health

Faeth, P. (2000). Fertile ground: Nutrient trading's potential to cost-effectively improve water quality. *WRI World Resources Institute*, *7*, 16.

Fales, M. & Byrum, J. Saginaw Bay Watershed conservation partnership. *The Nature Conservancy and Michigan Agri-Business Association.*

Giri, S., & Nejadhashemi, A. P. (2014). Application of analytical hierarchy process for effective selection of agricultural best management practices. *Journal of Environmental Management*, *132*, 165-177.

- The ranking of best management processes with analysis of different scenarios were used to consider different dimensions of potential agricultural issues as related to economics and environmental concerns.

Gunther, A., & Jacobson, L. (2002). Evaluating the ecological condition of the South Bay: A potential assessment approach. *Center for Ecosystem Management and Restoration*.

- This study presented a proposal of how to determine the health of estuarine ecosystems based on specific indicators.

Hand, J. P. (2004). Protecting the seventh generation Saginaw Chippewa Tribe serves as natural resources trustee. *MICHIGAN BAR JOURNAL*, *83*, 28-31.

Hartig, J. H., & Law, N. (1994). Institutional frameworks to direct development and implementation of Great Lakes remedial action plans. *Environmental Management*, *18*(6), 855-864.

- The focus on continually analyzing and improving remedial action plans attempts to give a greater impact though restoration efforts.

Hartig, J. H., Zarull, M. A., Reynoldson, T. B., Mikol, G., Harris, V. A., Randall, R. G., & Cairns, V. W. (1997). Quantifying targets for rehabilitating degraded areas of the Great Lakes. *Environmental Management*, *21*(5), 713-723.

- The setting of targets of ecosystem health can help to determine impairment status and allow for reaching an agreement on remedial action plans.

Mitsch, W. J., & Bouchard, V. (1998). Enhancing the roles of coastal wetlands of the North American Great Lakes. *Wetlands Ecology and Management, 6*(1), 1-3.

- The loss of the coastal wetlands, through human development, which served as protectors for the lake by collecting toxins, has had a great impact on the health of the Saginaw Bay and Lake Huron. The restoration of these wetlands is suggested as a way to improve overall water quality.

Mitsch, W. J., & Wang, N. (2000). Large-scale coastal wetland restoration on the Laurentian Great Lakes: Determining the potential for water quality improvement. *Ecological Engineering*, *15*(3), 267-282.

- A simulation and wetland distribution models were developed to determine the effects of wetland restoration in reducing nutrient loads to the Saginaw Bay.

Nerenberg, S. B. (2000). Lessons learned from three watershed-sensitive development demonstration projects in the Great Lakes basin. *National Conference on Tools for Urban Water Resource Management and Protection Proceedings, 2*56-263.

- Sensitive design in constructing subdivisions was a goal of the Conservation Development projects of The Conservation Fund.

Petrzelka, P. (2012). Absentee landowners in the Great Lakes Basin: Who they are and implications for conservation outreach. *Society & Natural Resources*, *25*(8), 821-832.

- The incorporation of different methods of outreach to include absentee landowners will be beneficial in continuing conservation work.

Petrzelka, P., Buman, T., & Ridgely, J. (2009). Engaging absentee landowners in conservation practice decisions: A descriptive study of an understudied group. *Journal of Soil and Water Conservation*, *64*(3), 94A-99A.

- A goal of including absentee landowners in the ideals of conservation practices was highlighted.

Petrzelka, P., & Marquart-Pyatt, S. (2011). Land tenure in the US: Power, gender, and consequences for conservation decision making. *Agriculture and Human Values*, *28*(4), 549-560.

- Analysis of landowner dynamics and how they relate to and affect conservation efforts.

Pijanowski, B. C., Long, D. T., Gage, S. H., & Cooper, W. E. (1997). A land transformation model: Conceptual elements, spatial object class hierarchies, GIS command syntax and an application for Michigan's Saginaw Bay Watershed. *Land Use Modeling Workshop.*

PS Consultants (2000). Measures of success: Addressing environmental impairments in the Saginaw River and Saginaw Bay.

Ricciardi, A., & Simberloff, D. (2009). Assisted colonization is not a viable conservation strategy. *Trends in Ecology & Evolution*, *24*(5), 248-253.

- This paper states that the translocation of species that are endangered in a particular area could cause unforeseen trouble when moved outside their natural habitat range. Though conservation has used risk assessment this paper argues the danger in adjusting species habitat.

Sanchez, G. M., Nejadhashemi, A. P., Zhang, Z., Woznicki, S. A., Habron, G., Marquart-Pyatt, S., & Shortridge, A. (2014). Development of a socio-ecological environmental justice model for watershed-based management. *Journal of Hydrology*, *518*, 162-177.

- Spatial multifactor models were used to explore the differences associated with varying areas of human disturbances on streams as well as IBI models that demonstrated stream health.

Sedell, J. R., Steedman, R. J., Regier, H., & Gregory, S. V. (1991). Restoration of human impacted land-water ecotones. In *Ecotones* (pp. 110-129). Springer US.

- Importance was given to the management and ecosystem models that are region specific in contrast to wide range types to be more effective in restoration efforts.

Selzer, M., & Bureau, W. (2008). The Michigan Department of Environmental Quality biennial remedial action plan update for the Saginaw River/Bay area of concern.

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

- Past, present and future restoration efforts in the Saginaw Bay Watershed were examined.

VanHouten, J. W. (2014). Large watershed management and restoration: Dioxin sediment remediation case study. *International Journal of Environmental Studies*, *71*(4), 570-577.

- This paper evaluated different aspects of dioxin remediation along with different ways to implement the proposed cleanup. This paper also touches on the EPA phase approach of remediation.

Weinbauer, I. (1998). A national program to restore the Great Lakes. *Restoration and Reclamation Review; Student On-Line Journal, 3*(3).

- The Ecological Protection and Restoration Program of the GLNPO of the USEPA.

<u>Socioeconomic Conditions</u>

VI. Socioeconomic Conditions

a. Economic Context

Batchelor, D., & Rogers, J. (2001). Designing a multiple market trading system for watershed management. *Proceedings of the Water Environment Federation, 2001* (12), 528-543.

- This discusses the changes that need to be made for the most successful outcome. An integrated network of laws that has ecological aspects considered may be more cost effective and yield a faster result than individual laws that focus on one type of pollution.

Faeth, P. (1999). Market-based incentives and water quality. *World Resources Institute.*

- Trading of nutrients is proposed as a way to reduce pollution emissions while still having credits or profits possible for the industry.

Greenhalgh, S., & Faeth, P. (2001). Trading on water. *Forum for Applied Research and Public Policy*; *Executive Sciences Institute Inc. 16*(1), 71-77.

- This paper gives an overview of water quality history, issues, and concerns throughout different areas of the world. The discussion of point source and non-point source pollutions shows the difficulty posed by the regulation of non-point source and the financial and technical problems associated with addressing point source pollution in less developed countries. Because of the different costs associated with different companies and their respective wastes, the idea of water trading allows for a cost effective way to obtain industrial benefits from water quality regulation.

Groothuis, P. A., Southwick, R., Foster-Turley, P. & Whitehead J. C. (2006). Economic values of Saginaw Bay coastal marshes with a focus on recreational values. *Michigan Department of Environmental Quality.*

- The employment of economic tools was used to attempt to quantify the monetary values of certain uses, resources, and purposes of the Saginaw Bay.

Nassauer, J. I., & VanWieren, R. Vacant property now and tomorrow. *thelandbank.org*

- The Genesee County Land Bank Authority is attempting to utilize the large amounts of vacant property to investigate other natural land uses and/or to engage the community to take care of their land and neighborhoods thus creating value for vacant land by contributing to a healthy and attractive place to live.

Nelson, C. M. (2001). Economic implications of land use patterns for natural resource recreation and tourism. *Department of Park, Recreation, & Tourism Resources; Michigan State University*.

- Natural resources are valuable for different reasons to different people. Trends of natural resource use, tourism, recreation, and land use were determined.

Phillips, N., Davenport, T., & Kohl, N. (1995). Saginaw Bay urban targeting project. *The 9th 1995 Conference on Coastal Zone.*

Reckhow, K. H. (1994). Water quality simulation modeling and uncertainty analysis for risk assessment and decision making. *Ecological Modeling*, *72*(1), 1-20.

- Scientific assessment of environmental risk analysis on water quality simulation models.

Whitehead, J. C., Groothuis, P. A., & Southwick, R. (2007). Linking recreation demand and willingness to pay with the inclusive value: Valuation of Saginaw Bay coastal marsh. *US Environmental Protection Agency Workshop, "Valuation for Environmental Policy: Ecological Benefits"*, No. 07-09.

- The Saginaw Coastal Bay land and the economic value attached to this area is addressed.

Whitehead, J. C., Groothuis, P. A., Southwick, R., & Foster-Turley, P. (2005). Economic values of Saginaw Bay coastal marshes. *Department of Economics Appalachian State University, North Carolina*.

- The employment of economic tools was used to attempt to quantify the monetary values of certain uses, resources, and purposes of the Saginaw Bay.

Whitehead, J. C., Groothuis, P. A., Southwick, R., & Foster-Turley, P. (2009). Measuring the economic benefits of Saginaw Bay coastal marsh with revealed and stated preference methods. *Journal of Great Lakes Research, 35*(3), 430-437.

- Estimation of the economic benefits of Saginaw Bay will aid in attaining conservation funding.

Yeboah, F. K. (2014). Exploring stakeholders' perspectives and preferences for attributes of policy interventions: Three essays from two different policy and geographical contexts. *Doctoral dissertation, Michigan State University.*

- A focus on stakeholder opinion and involvement in important environmental projects is considered, including the CREP filter strip program. Suggestions for improving participation in the CREP program were given.

b. Impact on Humans

Dai, D., & Oyana, T. J. (2008). Spatial variations in the incidence of breast cancer and potential risks associated with soil dioxin contamination in Midland, Saginaw, and Bay Counties, Michigan, USA. *Environmental Health, 7*(1), 49.

- The measurements of soil dioxins were compared to the spatial instances of breast cancer and they found a correlation between the soil dioxin concentration and the occurrence of breast cancer.

Garabrant, D. H., Franzblau, A., Lepkowski, J., Gillespie, B. W., Adriaens, P., Demond, A., Hedgman, E., Knutson, K., Zwica, L., Olson, K., Towey, T., Chen, Q., Hong, B., Chang, C., Lee, S., Ward, B., LaDronka, K., Luksemburg, W. & Maier, M. (2009). The University of Michigan dioxin exposure study: Predictors of human serum dioxin concentrations in Midland and Saginaw, Michigan. *Environmental Health Perspectives, 177*, 818-824.

- Serum dioxin concentrations were assessed and the identifications of the factors that contribute to it were examined to determine spatial variability.

Giesy, J. P., Kannan, K., & Jones, P. D. (2001). Global biomonitoring of perfluorinated organics. *The Scientific World Journal, 1*, 627-629.

- Widely used and degradation resistant FOCs were analyzed to determine persistence and toxicity in blood plasma and liver tissue.

Guajardo, O. A., & Oyana, T. J. (2009). A critical assessment of geographic clusters of breast and lung cancer incidences among residents living near the Tittabawassee and Saginaw Rivers, Michigan, USA. *Journal of Environmental and Public Health*, *2009*.

- Individuals living near the rivers were found to be at a higher risk for breast cancer and individuals that lived nearer to highways were more at risk for lung cancer.

Hedgeman, E., Chen, Q., Hong, B., Chang, C. W., Olson, K., LaDronka, K., Ward, B., Adriaens, P., Demond, A., Gillespie, B. W., Lepkowski, J., Franzblau, A. & Garabrant, D. H. (2009). The University of Michigan dioxin exposure study: Population survey results and serum concentrations for polychlorinated dioxins, furans, and biphenyls. *Environmental Health Perspectives*, *117*(5), 811.

- This study used random sampling to determine if there was statistical significance between a reference group and Saginaw and Midland populations that are exposed to PCDD/PCDFs due to localized chemical industry. Statistical significance was found although differences in concentrations were small and regression models were suggested as a continuation for analysis.